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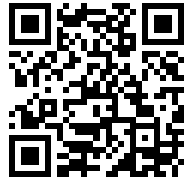

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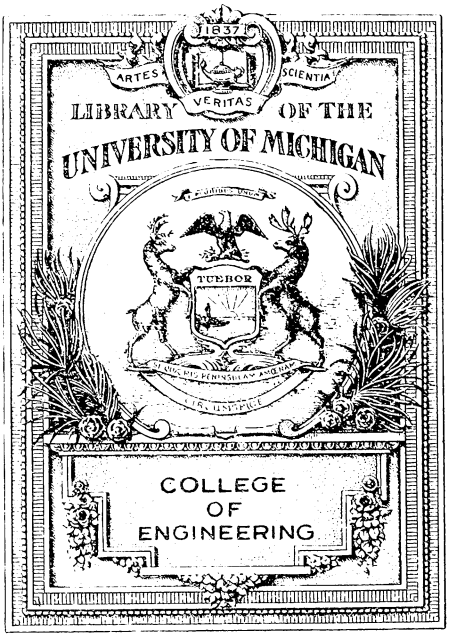

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THE
RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. I OCTOBER, 1919 NO. I

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THE
RADIO REVIEW

VOL. I OCTOBER, 1919 NO. 1

On the Goniometric Functions Applicable to Directive Aerials.

BY A. BLONDEL.

INTRODUCTION.

THE principle of the use of two adjacent antennæ to form loop aerials for directional waves has been known some considerable time.* These groups of two aerials have been used since 1902, in their simple form by the author, and in the form of a combination of two pairs of antennæ placed perpendicularly to one another by MM. Bellini and Tosi.

On the other hand, the author has also introduced the use of closed circuits equivalent to two aerials connected by junction wires at their upper and lower points. These separate systems have been put forward as means for determining at the receiving station the direction of the station from which the waves are being received. It has been proposed especially to allow ships to receive signals sent out by these directional stations ("*radio-phares*"), such as have already been installed by the Service des Phares Français, between 1911 and 1913, at the instigation of the author. Similar receiving apparatus was also installed about the same time on the Marconi Company's ships.

* The construction of simple frame aerials of two adjacent antennæ, such as are considered here, was described for the first time by the author in 1902 (British Patent 15527, July 11th, 1902); in the same patent is described the use of a closed frame for radio-goniometric purposes,

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MM. Bellini and Tosi have installed at Boulogne-sur-Mer, at Havre, and other places, fixed radiogoniometric stations capable of telegraphing their bearings to ships at sea.*

The International Convention of London, in 1911, fixed a maximum wave length of 150 metres for signals of this class.

Without wishing to discuss in what follows the respective advantages of the different radiogoniometric systems on land or on ships, it is proposed to indicate the manner in which the phase differences of the electromotive forces induced in the two vertical or nearly vertical parts of the measuring aerial necessitate important corrections, when the dimensions of the loop or frame are not very small compared with the wave length employed. The mathematical relations which indicate these corrections will be called the *goniometrical functions* in the following article.† It is interesting to study them in order to realise the difficulties which attend the use of short wave lengths in radiogoniometric work.

General Definition of Directional Aerials whose Goniometric Functions are to be Examined.

Although the system which is most favoured at present is the closed loop or frame aerial arrangement, I will consider the case of open aerial systems, in order to make this investigation as general as possible.

Aerial systems comprising two adjacent antennæ arranged in

---

and the author has described with some detail in German Patent 237486, January 15th, 1910, and in the descriptions of the apparatus shown by the Service des Phares at the Franco-British Exhibition, 1908, the use of these frames closed by a condenser, and the results obtained in experiments carried out aboard ship with the co-operation of General Ferrié and Commandant Brenot.

In March, 1910, the author took up with Commandant Brenot the study of these closed frames composed of several turns oscillating at their natural frequency, the circuit being closed by a condenser. The dimensions of these frames necessary to secure sufficient sensitiveness were unfortunately too large, but in October, 1915, General Ferrié had the happy inspiration of combining an amplifier with these frames, so as to obtain a considerable increase in the sensitiveness and at the same time to reduce the dimensions of the frame so that it could be easily turned round on a fixed axis. Radio-goniometers with small frames have entered into current practical use since that date, but they are not the object of the present article, which is confined to the previous type of construction.

* More recently M. Bellini has invented a very ingenious system of electrostatic excitation of double aerials.

† The subject of the investigation is limited to the determination of the goniometric functions for continuous and for damped waves; we shall not deal here with the other corrections, often very important, which arise through earth capacity or capacity to neighbouring objects, nor with corrections arising from the construction of the moving part of the radio-goniometers, nor with corrections arising from induced currents in the hull or other metal parts of the vessels, or in any other aerials fixed on the same ship.

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the same vertical plane, at a distance $2x$ (less than, or equal to, a half wave length), and brought into resonance (by means of loading inductances or capacities in series) with the frequency of the waves to be received, may be of two different types, according to the mode of connection; these are :—

(1) *Type "D" (Differential)*, in which the inductive effects of the aerials on the receiving circuit are opposed when the aerials are in the plane of the waves. The resultant induced current is a maximum when the plane of the loop coincides with the direction of propagation of the waves and is a minimum when it is perpendicular to that direction.

(2) *Type "S" (Additive)*, in which the inductive effects on the receiving circuit are additive. The positions of maximum and minimum induced current are the inverse of those of the first type.

The loop aerial with several turns can be treated in the same manner as type "D" by multiplying the electromotive forces induced in the two vertical portions of the aerial by the number of turns on the frame.

In order to simplify matters, I will assume that the waves are being propagated along the surface of the sea, and that, in consequence, there is no horizontal component of the E.M.F. vector, such as has been shown by Zenneck to exist in the case of propagation along the ground. We are therefore justified in neglecting all the horizontal connections between the antennæ and, when dealing with oblique parts, considering the vertical component only of the electric force.

Principle of the Methods.

With the above assumptions it is necessary to distinguish between two methods of determining the direction of the waves, using either of the above types of aerial :—

(1) *The zero method* consists in determining the position of maximum and minimum current as indicated by the detector. The two directions corresponding to the minimum audibility in the telephones are determined, and the angle between them bisected. The accuracy of the measurements diminishes, however, as will be shown later, when the plane of the loop aerial approximates to the direction of propagation of the waves.

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(2) *The comparison method* is based upon the comparison of the currents induced in two or more loop aerials fixed at known angles to one another.* This necessitates a previous knowledge

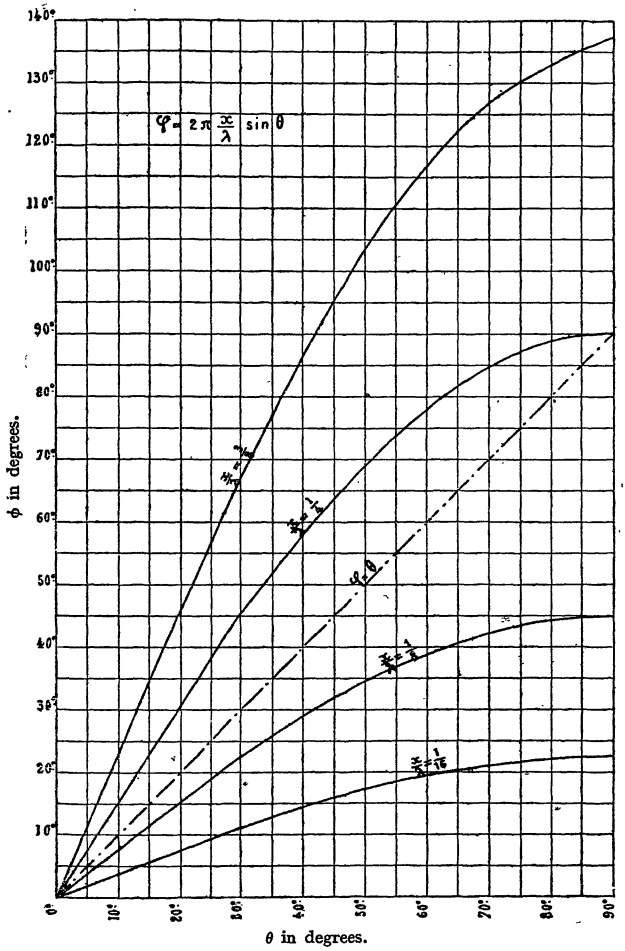

FIG. 1.

of the laws governing the variation of current in the aerial with the direction of the incident waves. For simplicity I shall call this law the "goniometrical function," and represent it by gon θ, where θ is the angle between the plane of the loop and the horizontal line perpendicular to the direction of propagation of the waves.

* *Compare* German patent No. 237456, January 15th, 1919.

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I. GONIOMETRICAL FUNCTIONS USING CONTINUOUS WAVES.

If continuous waves of wave length λ are being received and we neglect the transitory effect at the commencement of the signal, it is easy to determine the respective goniometrical functions of the two types of aerial systems. Let $e_0 = E \sin \omega t$ represent the E.M.F. induced in an imaginary simple aerial, placed at the central vertical axis of the loop, and having the same constants as each of the real aerials. This aerial is supposed to act on the detector by means of an imaginary jigger similar to the real jiggers. Let $F(e_0)$ represent the effect on the receiving instrument, F being the function depending on the properties of the detector, in accordance with the most generally accepted hypothesis.

Let the two antennæ of the aerial system be distant x and $-x$ from the imaginary central aerial, and let all the circuit constants be the same, then $F(e_0)$ will be replaced by $F(e_1 - e_2)$ for loops of type D, and by $F(e_1 + e_2)$ for type S loops.

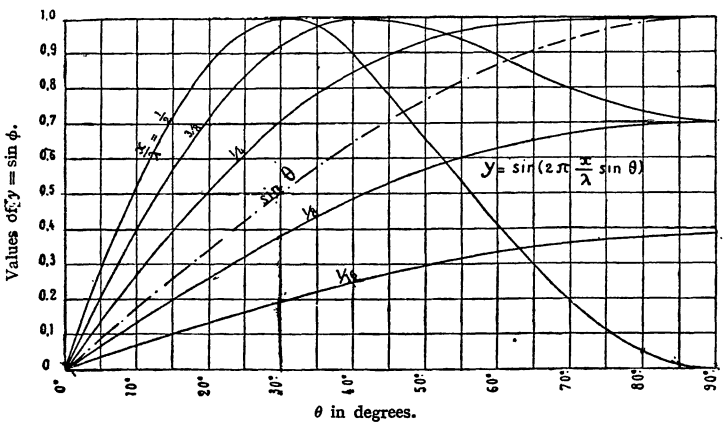

FIG. 2.

Thus putting $\xi = \dfrac{x \sin \theta}{\lambda}$ and $\phi = \dfrac{2\pi x \sin \theta}{\lambda}$ we have,

Type D: $e_1 - e_2 = 2e_0 \sin 2\pi\xi = 2e_0 \sin \phi$; . . (1)

Type S: $e_1 + e_2 = 2e_0 \cos 2\pi\xi = 2e_0 \cos \phi$ . . (2)

The functions gon θ, relating to the two types of loop, are obtained by dividing these expressions by $2e_0$. They are purely geometric functions, independent of the absolute value of the

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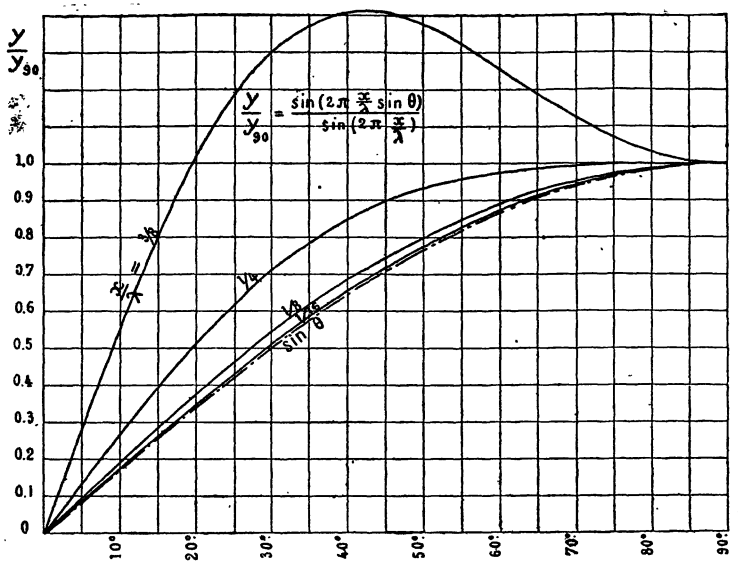
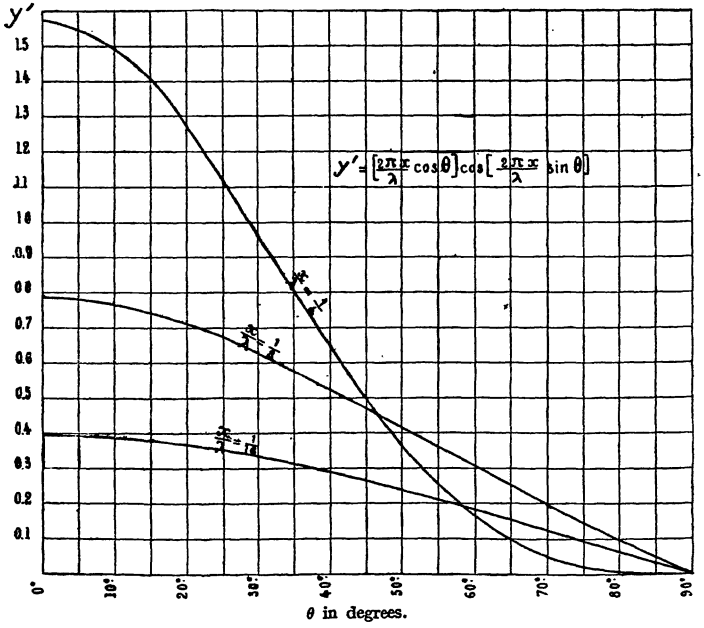


θ in degrees.

FIG. 3.



θ in degrees.

FIG. 4.

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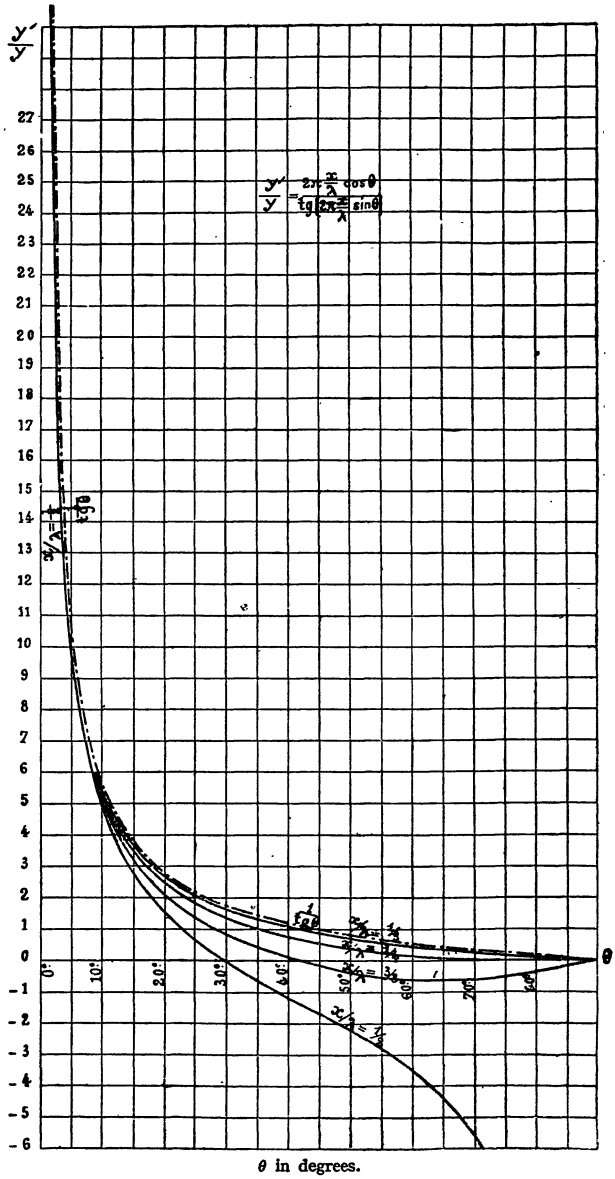
E.M.F., *i.e.*,

$$\text{gon}_D\,\theta = \sin\phi \quad . \quad . \quad . \quad . \quad . \quad (3)$$
$$\text{gon}_S\,\theta = \cos\phi \quad . \quad . \quad . \quad . \quad . \quad (4)$$



θ in degrees.

Fig. 5.

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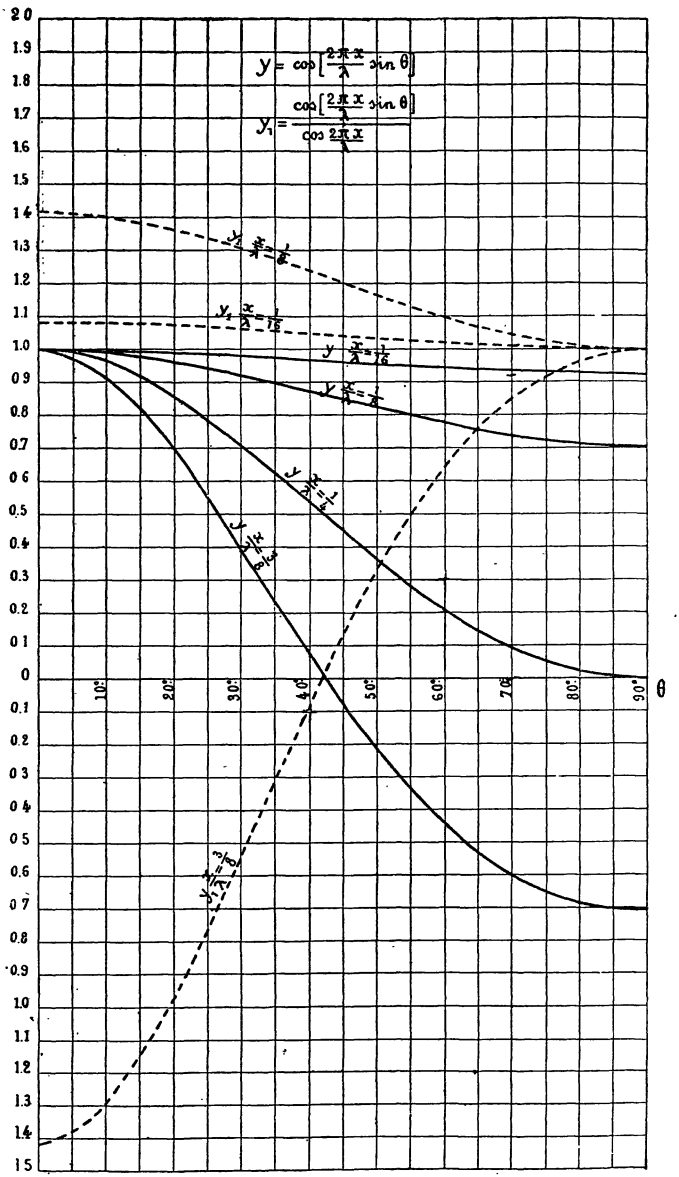
Figs. 1 to 8 review graphically the properties of the two types (D and S) of aerials.



θ in degrees.

FIG. 6.

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Fig. 1 shows the variation of ϕ as a function of θ for different values of the ratio $\frac{x}{\lambda}$; Fig. 2 gives the variation of sin ϕ, and Fig. 3 the variation of the ratio of sin ϕ to its value when $\theta = 90°$.

Fig. 4 shows the value of the differential y' of sin ϕ, a derivative which gives an idea of the sensitiveness of measurement. When an energy integrating detector is used, the sensitiveness is proportional to $2yy'$, and can be obtained by multiplying together the ordinates of the two preceding curves.

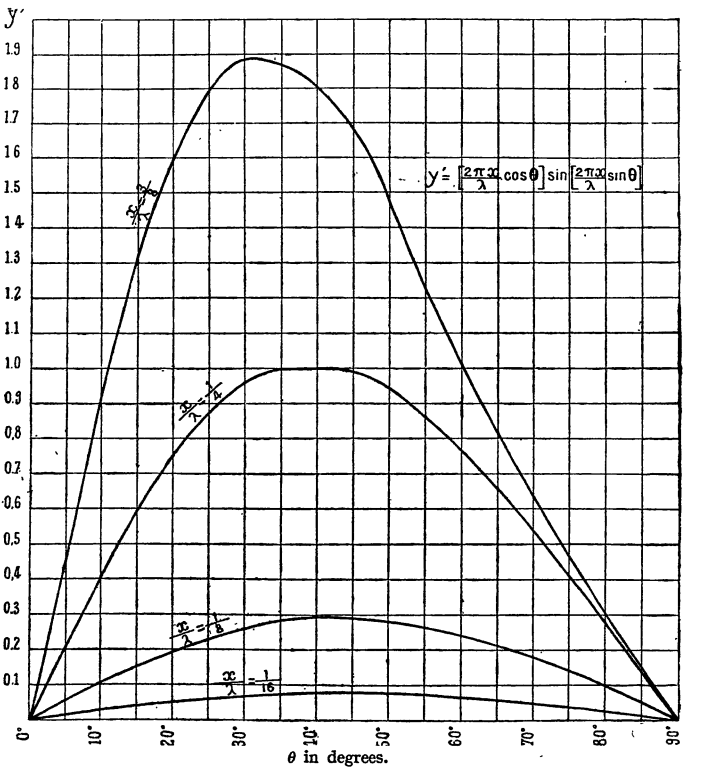

FIG. 7.

Fig. 5 gives the relative sensitiveness ratio, that is, the logarithmic derivative y'/y. For an energy integrating detector this derivative becomes $2y'/y$.

Figs. 6, 7 and 8 give corresponding values of y, y' and y'/y for the case of S type loops. It will be seen from these curves

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that the properties of the two types of loop aerial are altogether different, and do not show to the advantage of the S type, since in the latter case y' always becomes zero, not only when $\theta = 90°$ but also when $\theta = 0$.

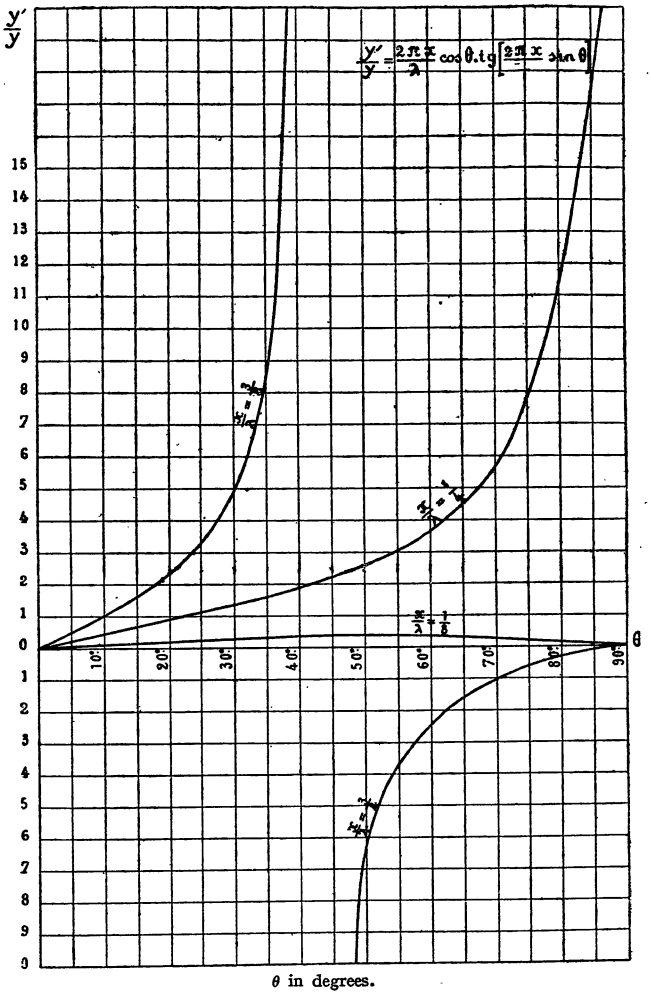

FIG. 8.

(To be continued.)

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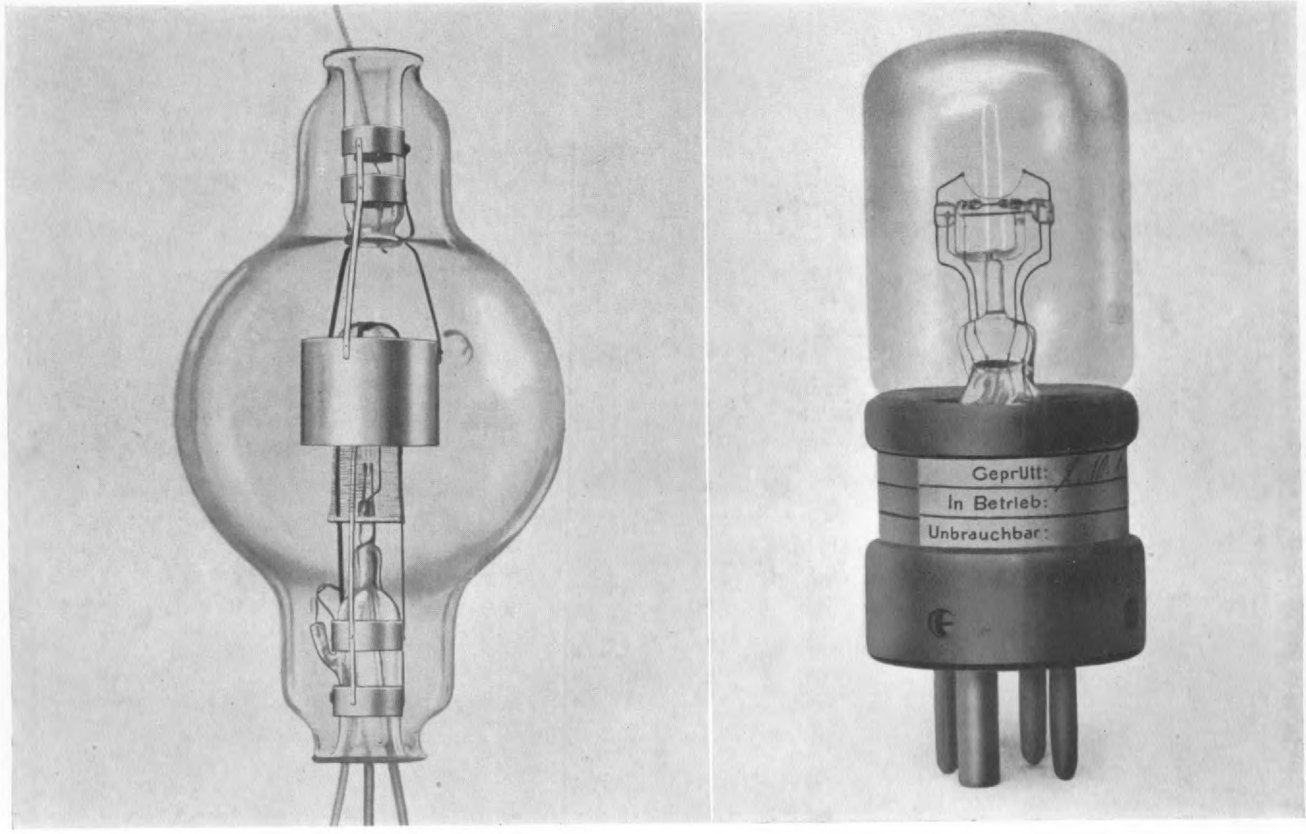

(c) *British.* (d) *German.*

TYPICAL MODERN "HARD" TRIODE VALVES.

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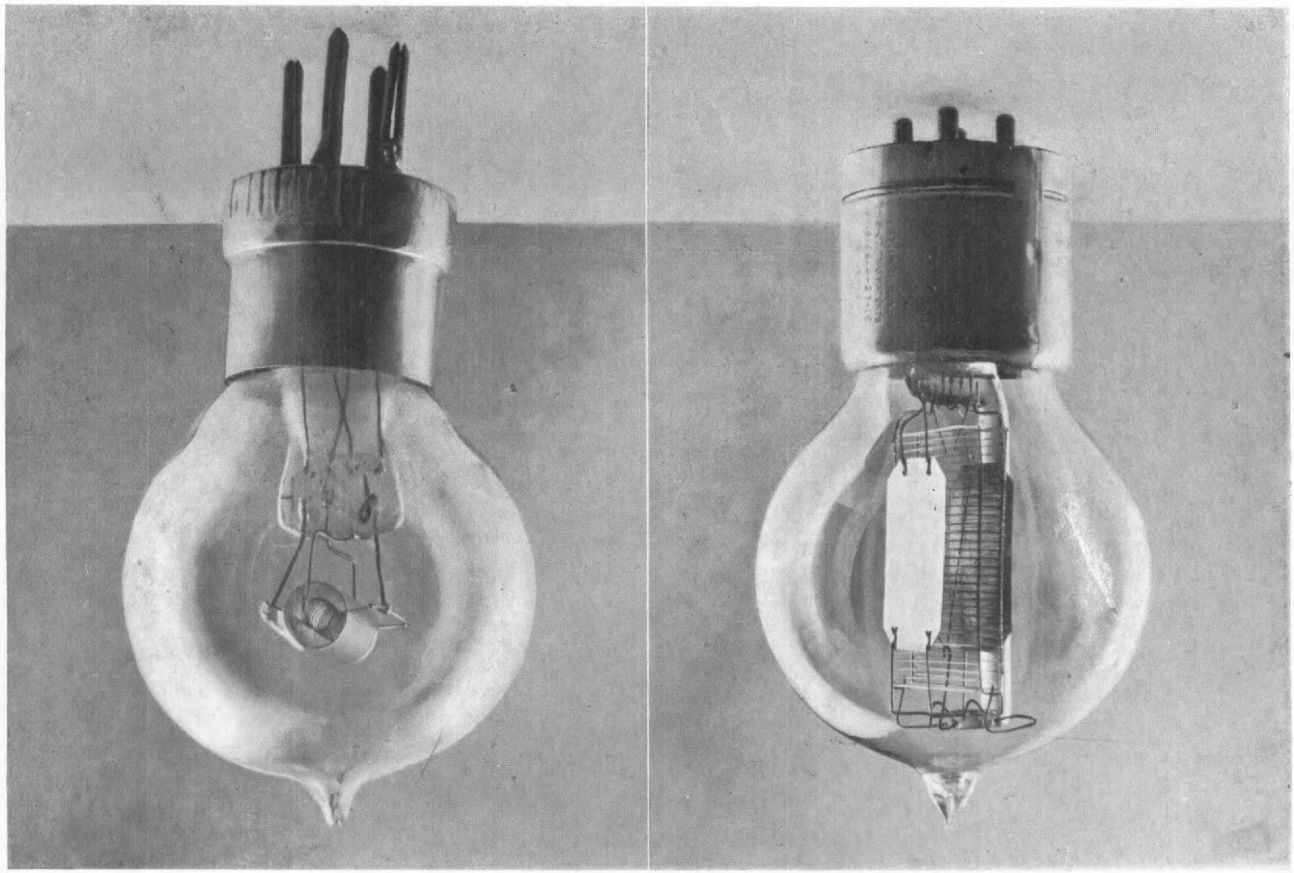
(a) American. (b) French.



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An Investigation of the Internal Action of a Triode Valve.

BY W. H. ECCLES, D.Sc., M.I.E.E.

THE most important single instrument in modern wireless practice is the three-electrode thermionic vacuum valve, for it enters into every main division of the subject—it plays a dominant part in the generation of oscillations, the detection of signals and in the amplification of feeble voltages and currents. Its arrival and development have, besides, helped greatly towards the success of apparatus and methods that might otherwise have remained almost failures. It is, therefore, very appropriate that an account of some of its properties, and an attempt to advance our understanding of these properties, should find a place in the first number of a new wireless journal. In order to avoid the repeated use of the long name used above, the instrument will here be called a triode valve, or, more briefly still, a triode; a valve with two electrodes will be called a diode. The term "triode" includes the proprietary articles known as the audion of de Forest, the valve of Round, and the pliotron of Langmuir; the term "diode" covers the original Fleming valve and the kenetron rectifier, for example.

In its most usual forms the triode consists of a heated filament of tungsten, a metal plate or cylinder of refractory metal, and a grid, all enclosed in a very highly exhausted bulb; and in the modes of employment we are to study, the plate or cylinder is maintained at a positive electric potential relative to the filament, while the grid is given voltages considerably smaller than the plate. All the current across the vacuum is carried by electrons produced by evaporation from the heated filament. The filament is nearly always heated by an independent current, but in exceptional types of triode the source of electrons might be a hot plate heated electrically or by a "burning glass"; and, therefore, in general it is better to call the source of electrons the cathode of the tube. The plate or cylinder may be called the anode

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whatever its shape. The third electrode, which, as already said, is usually a grid between cathode and anode, may really be a conductor of any shape, and need not, even, be situated between anode and cathode; and since its function is to regulate and control the flow of the electrons from cathode to anode, it may in general be called the control electrode. The names anode and cathode come from general electrical terminology, and imply that the current traversing the vacuum appears to enter the vacuum at the plate and leave it at the filament.

The action of the triode depends mainly upon two phenomena, one known as the "space-charge effect" and due to the electric repulsions between free electrons, and one that may be called the "shielding action," exercised by the control electrode over the cathode and the space charge near it. The object of this paper is to study these phenomena and their consequences quantitatively.

THEORY OF THE SPACE CHARGE.

First, let us suppose the cathode and anode to be parallel planes. A sectional view is given in Fig. 1, the distance between the planes being taken as x_a and the distance of a typical plane layer from the cathode being x. We shall suppose the hot cathode to be maintained at zero potential and the plate to be maintained at a potential v_a above the cathode. The electric force in the typical layer will be F directed from anode to cathode, and therefore the mechanical force on an electron in that layer will be towards the anode and of magnitude Fq, where q is the magnitude of the negative charge of the electron. When a steady state has been attained a current i will be crossing each square centimetre of every plane between the anode and cathode and parallel to these. Let the number of electrons per cubic centimetre in the typical layer be n and the velocity of the electrons there towards the anode be u.

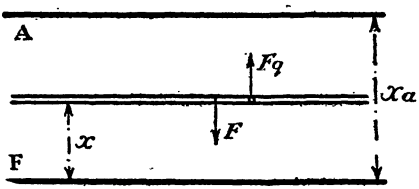

FIG. 1.

It will be noticed that because the positive direction of F has been taken opposite to the direction of increase of x the minus signs that usually appear in front of the differential coefficients are absent from the equations. This is very convenient for the present problem where we are dealing throughout with negative electricity.

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The equation connecting the current density i with the potential v at the distance x from the cathode has been given by C. D. Child in the *Physical Review* p. 498 (1911), and by I. Langmuir in the same journal p. 450 (1913). The equation is

$$v = (i/A)^{\frac{2}{3}} x^{\frac{4}{3}},$$

or

$$i = A v^{\frac{3}{2}}/x^2.$$

The value of A in practical units is $2{\cdot}33 \times 10^{-6}$.

In obtaining this solution the velocity of emission of the electrons from the cathode is assumed to be negligible. The electric field at the surface of the cathode must consequently be zero unless the saturation current is being taken. For suppose the current to be well below the saturation value; then more electrons are being emitted than are carried to the anode, and the balance is continually being returned to the cathode. This action takes place because the smallest accumulation of unwanted electrons leads immediately to the creation near the cathode of an electric field which pushes new electrons back again; consequently the accumulation of free electrons is automatically prevented and the electric field has no opportunity of becoming different from zero. If, however, the applied voltage between the plates is greater than that needed to produce the saturation current there will exist at the cathode a positive field that could carry away more electrons than are actually being emitted. This condition of zero field at the cathode, and also that of zero voltage, must be satisfied.

We may regard the v, i, x equation as showing the voltage at which an anode placed at the distance x from the cathode must be maintained in order to hold the unsaturated current i constant; or we may say that when we observe a current of density i being carried by electrons between two parallel planes distance x apart we know the voltage between the planes must be as given by the above equation. From the v, i, x equation we may obviously obtain the distribution of F, n and u. We find

$$F = \frac{4}{3}\left(\frac{i}{A}\right)^{\frac{2}{3}} x^{\frac{1}{3}},$$

$$nq = \frac{\kappa}{9\pi}\left(\frac{i}{A}\right)^{\frac{2}{3}} x^{-\frac{2}{3}}$$

$$u = \frac{9\pi}{\kappa} A^{\frac{2}{3}} i^{\frac{1}{3}} x^{\frac{2}{3}},$$

where κ is the electric inductivity of the vacuum.

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The distribution of these quantities between the electrodes is given by the curves of Fig. 2, which is not drawn to scale. The total charge in motion at any time between unit area of the plates is obtained by integrating nq with respect to x; it is

$$\frac{\kappa}{3\pi}\left(\frac{i}{A}\right)^{\frac{1}{3}} x^{\frac{1}{3}},$$

and is proportional to the value of the field at the anode. This

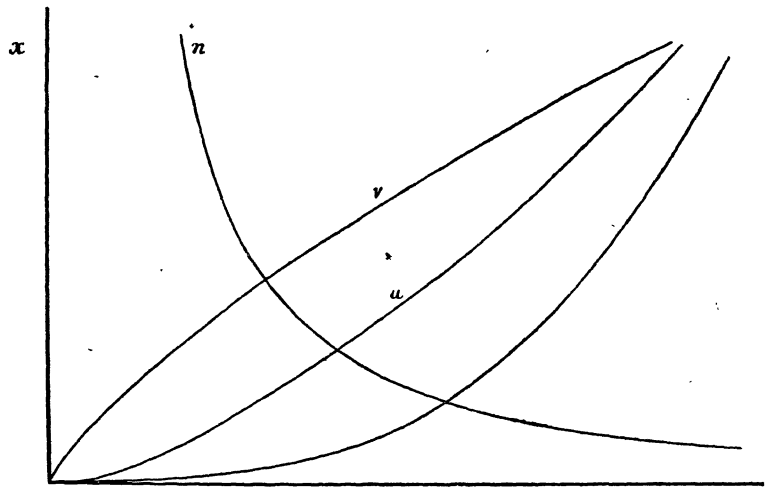

FIG. 2.

is directly evident from the consideration that the Faraday lines leaving unit area of the anode are $\kappa F/4\pi$ in number, and these are all occupied in reaching out, so to speak, to the negative electricity in the space between the plates.

In the preceding paragraphs the electrons are imagined to emerge from the cathode surface with negligible velocity. Let us now remove this limitation, and let us assume that they all leave the cathode with the same velocity u_1. If the current is unsaturated many electrons must be returned to the cathode by virtue of a negative electric field, and this field must be due to an accumulation of electrons at a distance from the cathode. At this place the field must be zero (for accumulation to be possible); and as F changes sign and passes through the zero value some of the electrons will be dragged towards the anode, some will be sent back to the cathode. Since F is the gradient of v it is evident

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that v is a minimum at this place of zero velocity; we shall call the co-ordinate of this place x_0. Moreover, as the differential equations must still be obeyed, the changes in the old solution must be confined to the introduction of arbitrary constants at permissible places. Inspection of the differentiations shows that we may write $v + v_0 = (i/A)^{\frac{2}{3}}(x - x_0)^{\frac{4}{3}}$,

whence $$F = \frac{4}{3}\left(\frac{i}{A}\right)^{\frac{2}{3}}(x - x_0)^{\frac{1}{3}}.$$

In these equations we have, as we should,

$$v = -v_0 \text{ at } x = x_0$$

and $$F = 0 \text{ at } x = x_0,$$

while F is negative when $x < x_0$, and positive when $x > x_0$. Continuing the differentiations as before we obtain

$$nq = \frac{\kappa}{9\pi}\left(\frac{i}{A}\right)^{\frac{2}{3}}(x - x_0)^{-\frac{2}{3}}$$

and $$u = \frac{9\pi}{\kappa}A^{\frac{2}{3}}i^{\frac{1}{3}}(x - x_0)^{\frac{2}{3}}.$$

When i is held constant we may represent the state of affairs between the electrodes by the curves of Fig. 3.

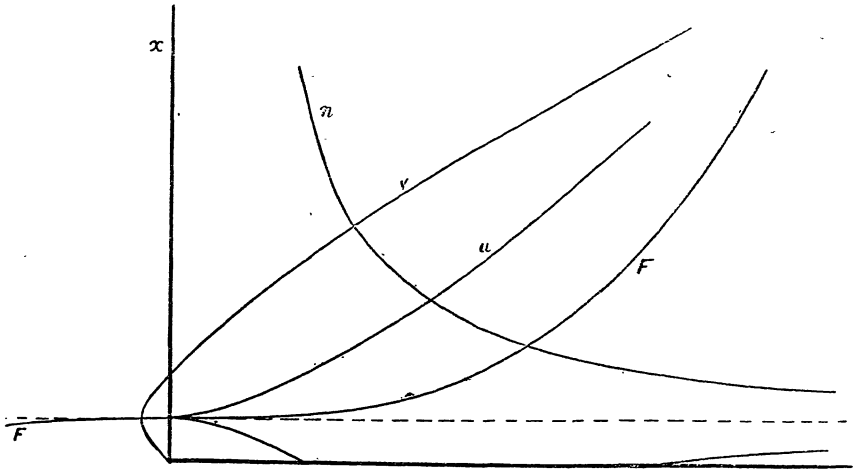

Fig. 3.

The curves may be interpreted as follows: An electron leaving the cathode and moving up the page finds itself in a retarding field by which its initial velocity u_1 is reduced to zero by the time it arrives at x_0. Here the retarding field changes sign and the potential reaches its minimum value v_0. A consequence of the

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slowing down of the electrons is that their density n increases to a very large value at x_0, the density multiplied by the velocity being, of course, constant because the current constituted by their motion is constant. Some of these accumulated electrons may be assumed to return sooner or later to the cathode, and some pass onwards under the influence of the positive field and rising potential; beyond x_0 the electrons gather speed and become less closely packed, as is seen from the curves of u and n.

We may estimate the magnitude of x_0 by putting v and x zero in the voltage equation above. We thus obtain

$$x_0^2 i = A v_0^{\frac{3}{2}}.$$

In practical units $A = 2{\cdot}33 \times 10^{-6}$, and it is known that the mean velocity of the electrons emitted from a cathode at a temperature of 2500°K corresponds to about 0·2 volt. Let us assume that i is, in a particular experiment, of magnitude 2 milliamperes. Then

$$x_0 = \left(\frac{2{\cdot}33 \times 10^6 \times (0{\cdot}2)^{\frac{3}{2}}}{2 \times 10^{-3}}\right)^{\frac{1}{2}} \doteqdot 10^{-2} \text{ cm.}$$

The distance x_0, which is of order a tenth of a millimetre, may therefore be regarded as small compared with the dimensions of any ordinary thermionic tube. Closer calculation indicates that this is likely to be rather too small than too large; but using the numbers just obtained we have, when $i = 2$ milliamperes,

$$v + 0{\cdot}2 = 74\,(x - 0{\cdot}01)^{\frac{3}{2}}$$

$$F = 99\,(x - 0{\cdot}01)^{\frac{1}{2}}$$

It should be noticed that x_0 is smaller the greater the current.

The formation of a place of accumulation of electrons, and of a place of zero field, at a short distance x_0 from the cathode reduces the case of electrons with finite initial velocity to that of a preceding page in which the initial velocity was taken to be zero. In every case, then, we may sum up the matter by saying that when the current and voltage carried by the space charge are small enough there is a place of zero field; an increase of voltage calls up an increase of current and a corresponding increase of the number of moving electrons, and the electric force due to this new distribution of the charge is just right to restore a layer of zero field. If there are not sufficient electrons to restore zero field the potential gradient becomes positive everywhere and the current is saturated.

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It has been assumed in the above discussion that the velocity of emission of the electrons has a definite value u_1 the same for every electron. This is not true, for the evaporated electrons have, in fact, a large range of velocities. The result is that instead of a layer of accumulated electrons of infinitesimal thickness and infinite density at a definite distance x_0 we expect a vaguely defined region of finite thickness and density in which sufficient electrons accumulate to produce the negative electric field needed for repelling the unwanted electrons back into the cathode.

Cathode and Anode Concentric Cylinders.

When the electrodes are of the form discussed in the preceding pages and illustrated in Fig. 1, analysis similar to that employed in the last few paragraphs may be applied to find the distribution of the space charge, but a complete discussion demands more mathematics than is desirable in this paper. Readers may refer to I. Langmuir's paper in the *Physical Review* of November and December, 1913, where it is shown that when the radius of the filament is less than a tenth of the radius of the cylindrical anode the current j per centimetre of the length of the concentric electrodes tends towards a lowest value given by

$$j = \frac{2\sqrt{2}}{9}\sqrt{\frac{q}{m}}\cdot\kappa\frac{v^{\frac{3}{2}}}{x}$$

as the ratio of the filament radius to the anode radius becomes smaller. Here x is the distance from the axis of the filament and v the potential at that point above that of the filament.

The current density at any point distant x from the axis of the filament is given by

$$i = \frac{j}{2\pi x} = \frac{\sqrt{2}}{9\pi}\sqrt{\frac{q}{m}}\ \kappa\frac{v^{\frac{3}{2}}}{x^2}.$$

In practical units the formulæ become

$$j = 14{\cdot}65 \times 10^{-6}\ \frac{v^{\frac{3}{2}}}{x}$$

$$i = 2{\cdot}33 \times 10^{-6}\ \frac{v^{\frac{3}{2}}}{x^2}.$$

When the radius of the cylindrical anode is not very great compared with the radius of the cathode, a correcting factor must be applied to both the last formulæ. The multiplier depends

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upon the ratio of the anode radius x to the cathode radius r' in the following manner:—

r'/x	0·067	0·10	0·15	0·2	0·3	0·4	0·5	0·6	0·7	0·8	1·0
multiplier	1·02	1·06	1·18	1·32	1·75	2·41	3·61	6·00	10·9	23·3	∞

This table may be applied in order to make rough allowances for the case when, for instance, the cathode is in the form of a curly filament, or is a bundle of parallel filaments.

THEORY OF THE CONTROL ELECTRODE.

Consider three conductors in space, as indicated in Fig. 4, and suppose an electric charge given to each. We shall suppose that the conductor marked 1 is raised to a much higher electric potential than either 2 or 3, and that we wish to inquire how the charge on 2 is connected with the voltages between the three bodies. We know from elementary electrostatic theory that q_2, the charge on conductor 2, is given by

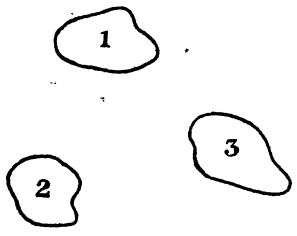

FIG. 4.

$$q_2 = c_{12}v_1 + c_{22}v_2 + c_{23}v_3,$$

where v_1, v_2, v_3 are the absolute electrical potentials of the three conductors, and c_{12}, c_{22}, c_{23} are what are called "capacity co-efficients." Let us suppose that the potential of 1 relative to conductor 2 is maintained by a connecting wire passing from 2 through a battery of voltage e_1 to conductor 1, and that a similar wire and battery of voltage e_3 connects 2 to 3. Then

$$v_1 = e_1 + v_2 \text{ and } v_3 = e_3 + v_2.$$

The connecting wires and batteries are assumed to have capacitance quite negligible compared with that of any one of the conductors 1, 2 or 3. The above equation becomes

$$q_2 = c_{12}e_1 + c_{23}e_3 + (c_{12} + c_{22} + c_{23})v_2.$$

If we take v_2 as the zero of electric potential for our problem, we have

$$q_2 = c_{12}\{e_1 + (c_{23}/c_{12})e_3\}.$$

We shall write g for the ratio c_{23}/c_{12}, and then the equation becomes

$$q_2 = c_{12}(e_1 + ge_3).$$

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This equation shows that when e_1 is increased by, say, one volt, the charge q_2 can be maintained at its old value by reducing e_3 to the extent of one g–th part of a volt. In other words, as regards effect on conductor 2, one volt on 3 is worth g volts on 1. The number g may or may not be greater than unity—that depends on the electro-geometrical constants c_{12} and c_{23}, which are sometimes called " mutual capacitances."

In order to make the matter less vague we may take a simple case and perform the necessary calculations. Let the three conductors be spheres of radii r_1, r_2, r_3, separated by distances x, y, z, much greater than the radius of the largest sphere, as represented in Fig. 5. By a very fundamental principle of electrostatics the absolute electric potential of any sphere, say number 1, is made up by algebraic addition of the scalar potential due to the charge on itself, of that due to the charge on 2, and that due to the charge on 3. Therefore

$$v_1 = \frac{q_1}{r_1} + \frac{q_2}{z} + \frac{q_3}{y}.$$

Similarly

$$v_2 = \frac{q_1}{z} + \frac{q_2}{r_2} + \frac{q_3}{x},$$

$$v_3 = \frac{q_1}{y} + \frac{q_2}{x} + \frac{q_3}{r_3}.$$

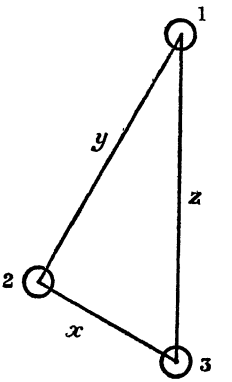

Fig. 5.

On solving these equations for q_2 we find (neglecting a constant factor not needed in our present application) that

$$q_2 \propto -\left(\frac{1}{zr_3} - \frac{1}{xy}\right)v_1 + \left(\frac{1}{r_1 r_3} - \frac{1}{y^2}\right)v_2 - \left(\frac{1}{xr_1} - \frac{1}{yz}\right)v_3.$$

The coefficients of v_1, v_2, v_3 are capacity coefficients of the system, and by comparing with the general equation for q_2 above we see that in our present problem

$$g = \left(\frac{1}{xr_1} - \frac{1}{yz}\right) \div \left(\frac{1}{zr_3} - \frac{1}{xy}\right).$$

To prepare for numerical examples take $r_1 = r_3 = r$, that is, let the spheres be of equal radii, then

$$g = \frac{yz - r}{xy - r} \doteqdot \frac{yz}{xy} \doteqdot \frac{z}{x}.$$

This result shows that, when the conductors are small compared with the distances between them, the value of g is equal to the

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ratio of the distances of 1 and 3 from 2, and is independent of the distance of 1 from 3. For example, if $z = 3x$, as in all the cases of Fig. 6, the value of g is 3, and, therefore, one volt applied between 3 and 2 is worth three volts applied between 1 and 2, as regards effect upon the charge on 2.

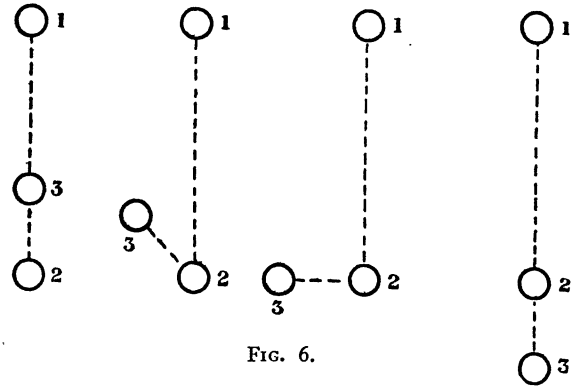

FIG. 6.

In this discussion the conductor 1 is the analogue of the anode of a triode, 2 corresponds to the cathode, and 3 to the control electrode. The charge q_2 on the cathode, being equal to the number of lines of electric force ending on the cathode, may be taken as the measure of the average electric field near the anode. All this applies strictly to a triode when cold; but when the cathode is emitting electrons the presence of the space charge must have an effect—for instance, it is well known that the mutual capacitance between the electrodes of any ordinary triode valve is from two to four times as great when the space charge is present as when it is absent—and but for this effect we could assume at once that the charge q_2 could be taken as a measure of the average electric field near the anode and also of the electron current leaving the cathode. The theory of any control could then be attempted in the manner sketched above. In particular, we could immediately make use of Maxwell's well-known solution for the shielding action of a grid of equal, parallel, evenly-spaced wires placed between and parallel to a plane anode and cathode (Maxwell's "Electricity and Magnetism," p. 248, first edition). The presence of the space charge, especially the dense portion near the filament, compels us, however, to adopt a direct method of calculation in preference to the method of quoting a geometrical formula and endeavouring to adapt it.

(To be continued.)

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The Radio Review: Its Policy and Aims.

BY THE EDITOR.

ENGLISH-SPEAKING workers in the field of radiotelegraphy have long felt the need of a high class periodical, devoted entirely to the development of this branch of applied science. The literature of the subject is already very extensive, but it is scattered throughout a number of scientific periodicals, and it has been a matter of considerable difficulty for one interested primarily in radiotelegraphy to consult the various papers to which reference is frequently given unless he has convenient access to a good scientific library. The same difficulty is met with in the attempt to keep one's self informed on the current development of the subject in all its many aspects. This want has been increasingly felt during the last few years. The developments connected directly or indirectly with radiotelegraphy and telephony have been so far-reaching, the amount of research work in connection therewith has been so great and so fruitful, and the number of people interested in the subject has so increased, that the demand for such a periodical has become imperative.

With the happy termination of the war this demand will undoubtedly become more insistent, and the moment seemed opportune to launch this new venture with every prospect of success.

The sole aim of the RADIO REVIEW will be to record the scientific developments of radiotelegraphy, and of those branches of allied science which are related to that subject.

It is our desire and intention to make the RADIO REVIEW as useful as possible to all interested in radiotelegraphy. For this reason it has been decided to issue it monthly, in order that no delay may be experienced in the publication and dissemination of scientific information.

In addition to original contributions, the magazine will contain a complete digest of the current literature of the subject in all countries, and translations of important papers appearing in other languages. For these to be useful it is important that they be up-to-date, and this will be made possible by the monthly issue.

It is intended to devote a certain amount of space to corre-

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spondence, and it is hoped that radio-engineers and scientific workers will take advantage of this opportunity of stating their own views and opinions, and of criticising those of others.

Proceedings of scientific societies in so far as they are concerned with radiotelegraphy will be recorded.

It is hoped that full use will be made of the RADIO REVIEW as a medium whereby all workers in the field of radiotelegraphy may communicate the results of their work and their opinions to their fellow workers, and to the ever increasing number of those interested in the subject.

The scope of the RADIO REVIEW will be kept as broad as possible. It will seek to cover the whole range of the subject, theoretical and practical, physical and mathematical, electrical and mechanical.

We are undoubtedly approaching a time of great and important developments along all these lines. During the stress of war the theoretical investigation of the physical properties underlying the many devices which were evolved was necessarily postponed. Those best able to carry out such investigations were engaged on far less congenial but more imperative duties. These scientists are now returning to their laboratories with a great many problems needing research and elucidation, and, one may hope, with a Government and public more alive than of old to the necessity of supporting such investigations in every possible way. The coming period of reconstruction should, therefore, see a steady and increasing output of articles and papers recording and discussing the results of this research work.

We must not be satisfied, however, with merely elucidating the secrets of nature; we must utilise the discoveries so made to the fullest possible extent. Before the war we were certainly behind Germany in the practical realisation of new discoveries. The war demonstrated very clearly the folly and danger of allowing another country to take over the conceptions and inventions of British scientists and bring them to practical fruition, forming thereby the bases of new industries and the monopoly which comes from early and well-organised commercial development. It is essential that our manufacturers work hand in hand with our scientists and take up and seek to develop every scientific discovery, whatever the apparent difficulties may be. This will only be possible if manufacturing firms show a higher appreciation of the skilled scientist and of his work than they have in the past.

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Nothing has contributed more to the enormous development of many of the highly successful American and German manufacturing concerns than their realisation of the importance of securing a large number of highly-skilled scientists and giving them every facility to carry out research work on an appropriate scale.

As we said above, the RADIO REVIEW will cover both the physical and the mathematical side of the subject of radiotelegraphy. No radio-engineer is likely to underestimate the importance of the latter. It is the *sine quâ non* of organised progress in theory and of efficient design in practice. Until a phenomenon has been represented completely by mathematical symbols, its utilisation is dependent on intuition and on the primitive method of trial and error. It is only by their representation by relatively simple mathematical formulæ and curves that the many complex phenomena involved in radiotelegraphy can be comprehended and discussed. It enables one to come to decisions in a few minutes which would otherwise require hours; it enables a man of ordinary attainments to arrive with certainty at a result which would otherwise require the intuitive insight of a genius. We trust, therefore, that non-mathematical readers will appreciate this when articles are published which appear to them to be too mathematical, and remember that the fault, if it be one, is probably not with the writer of the article, but with the phenomena, which are so complex that such treatment is essential to their elucidation.

Radio-engineering involves many problems which are not electrical. In so far as they are not peculiar to radiotelegraphy, or to apparatus and machines specially adapted to radiotelegraphy, they do not come within the scope of the RADIO REVIEW. There are many mechanical problems, however, involved in the design of masts, guys, aerials, alternators, transmitting mechanisms, etc., which may properly be deemed to come within the scope of the RADIO REVIEW, and which we hope to see discussed in its pages.

In conclusion, we wish to say that we shall welcome any suggestions which may be forthcoming with regard to possible improvements in the magazine. Its success will depend upon the whole-hearted support of radio-engineers and scientists and all those interested in the scientific development of radiotelegraphy and telephony.

G. W. O. HOWE.

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The British Association Meeting at Bournemouth

Papers and Discussions of Radio Interest

SECTION A.

REPORT OF THE COMMITTEE ON RADIOTELEGRAPHIC INVESTIGATIONS.

During the past twelve months the war-time restrictions on wireless telegraphy have continued in operation. A few statistical records from British Colonial Radio Stations have been sent regularly to the Committee, and occasional information from other parts of the world has been received.

In connection with the solar eclipse of May 29th the Committee arranged for the carrying out of experiments on the effect of the eclipse on signals transmitted across the central line. The British Admiralty stations at Ascension and Azores transmitted continuously during the transit of the umbra across the Atlantic Ocean. Observing stations north of the Equator were for the most part asked to listen to Ascension for at least an hour round about the time when the umbra passed between themselves and Ascension; observers south of the Equator were asked for the most part to listen to the Azores. Certain selected stations north of the Equator were asked to listen to the Azores, so as to afford check observations upon the variations which might be observed in signals passing across the central line of the eclipse, and, similarly, selected stations south of the central line were asked to listen to Ascension. The American station at Sayville also transmitted a programme during a portion of the period of the eclipse, and arrangements were made for special experiments between Darien and the Falkland Islands, and between an Egyptian station and a South African station.

The main portion of the experiment hinged upon Ascension. The umbral cone passed from west to east, and was expected to affect in succession the strength in which signals were received at such stations as Demerara, Jamaica, the stations on the coast of the United States and Canada, stations in Ireland, England, France, Italy, in the Mediterranean and Egypt.

The following is a brief account of the preliminary reduction of the statistics received from various parts of the world :—

The shadow of the moon struck the earth first at dawn on the coast of South America, and swept across the continent in the course of half an hour, at first with enormous velocity, but losing speed as the Atlantic Ocean was approached. About the middle of the Atlantic Ocean, and near the Equator,

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the speed of the shadow was about one-third of a mile per second. On crossing the African Continent from the Gulf of Guinea to the Mozambique Channel the speed gradually increased, and the eclipse finished at sunset near Madagascar. The effects of the moving shadow were investigated under three heads :—

(1) Strays ;
(2) Signals not crossing the denser parts of the shadow ;
(3) Signals crossing through or near the umbra.

Strays.

These were bad on the day of the eclipse and on the preceding day in Europe, North America and in temperate latitudes on the Atlantic Ocean. They were very few in Central and South America and in the central equatorial Atlantic. In Central America the conditions were exceptional meteorologically, the day having less rain than nearly every day of the preceding three weeks. The preliminary survey of the results recorded throughout the part of the globe reaching from Constantinople to Rio Janeiro suggests that there was no outstanding occurrence in regard to frequency or intensity of strays that could be directly ascribed to the passage of the shadow.

Signals Not Traversing the Dense Shadow.

Many observations were made in Northern Europe and America on the signals from the Azores, which were arc signals of 4,700 metres wave length. The observing points extended from Berlin, through Holland, France, Italy, Spain and Great Britain, to stations near the Atlantic coast of the United States. There were no unusual variations in the strength of the signals from the Azores.

Another class of experiment comes under this heading. It was suggested by the effect sometimes observed at sunset or sunrise in which the twilight band, when on one side of a transmitting station, appears to strengthen, as if by reflection, the waves received at a station on the other side of the transmitting station. In order to test whether such reflections occurred during an eclipse, certain stations on the south of the central line of the eclipse were asked to listen to Ascension, which was also south of the central line. The stations at Durban and Port Nolloth (South-West Africa) found no trace of the effect, and, in fact, the former concluded that the signals from Ascension were rather worse after the eclipse began. An analogous experiment on the northern side was carried out by one of the Malta stations, and also at Rosyth, listening to Cairo, with similar conclusions.

Effect on Signals passing Across the Central Line.

Arrangements were made for the transmission of signals from the Darien Station of the Panama Canal zone, and several stations in South America attempted to receive the signals. The report from the Falkland Islands has not yet come to hand, and the other stations in South America did not succeed in picking up the signals. The only observations made on the

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earlier stages of the eclipse are those of Demerara listening to Ascension. Fluctuations in signal strength are reported, but no steady increase or decrease in strength. Ships at sea within the penumbra report a strengthening of all signals during the eclipse. The most striking results were obtained at some of the stations in France, Malta and Teneriffe. At Meudon and at Rousillon (near Lyons), the signals from Ascension were received practically only while the eclipse was in progress. Both Malta and Teneriffe found that the eclipse produced a great improvement in the strength of signals. On the other hand, Durban was unable to pick up Cairo, though this is usually possible; but Aden was picked up with greater intensity than normal. On the whole the records show that the improvement in signal strength reached its highest value long before the umbra intervened between the stations, and this value persisted after the umbra had passed; that is to say, if ionising processes are the cause of the change in the strength of signals, the results indicate that the processes are practically fully accomplished in a given region of the air before the arrival of the umbra at that place, so that there appears to be nothing left for the umbra to do in the few minutes of complete shadow it brings.

The thanks of the Committee are due especially to the Admiralty for arranging that their stations at Ascension and the Azores, and at Cairo, should transmit the necessary signals; and also to the American Government for making similar arrangements regarding Sayville and Darien. Thanks are due also to the American, French and Italian Governments, the Admiralty, the War Office, the Air Ministry and Marconi's Wireless Telegraph Co., Ltd., for undertaking observations and recording the variations in signal strength.

Discussion on Thermionic Valves.

W. H. ECCLES, "The Three-Electrode Thermionic Vacuum Tube and the Revolution in Wireless Telegraphy."

During the war dark hints reached the civilian that a revolution was taking place in wireless telegraphy, the principal agent in which was reported to be an instrument called a "valve," a "lamp," or a "tube." This instrument seemed to have risen suddenly into a predominant position among all the apparatus of the wireless experimenter and operator, and appeared to be of use in every corner of his outfit. The complete name of the instrument is the three-electrode thermionic vacuum tube. It must be emphasised that it is the three-electrode valve, and not the valve with two electrodes, that has been responsible for the overthrowing of the old methods and apparatus. That it has been a veritable revolution can be seen by comparing the common practice in wireless telegraphy of 1914 with that of 1919. In 1914 practically all the most powerful transmitting stations in the world generated waves by sparks, and signals were received at nearly all stations by means of crystal detectors or magnetic detectors. The spark method of generating waves involved the use of very large antennæ for spanning great distances; and at receiving stations which wished to listen to stations

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more than even 100 miles away very large aerial structures were customary. But if we look at the state of affairs to-day we find most of the high-power stations for long-distance transmission are "continuous wave" stations, that is, they produce uniform uninterrupted waves instead of a series of short gushes made by sparks; while at the receiving end new modes of detecting these continuous waves appropriate to, and taking advantage of, their uniformity in character have been introduced. This is where the three-electrode tube, in various adaptations, enters the arena. Taken together, the improvements at both ends of the span have made possible the use of smaller antennæ at transmitting stations, and have almost removed the necessity for any antenna at all at receiving stations. For example, under reasonable weather conditions, it is quite easy to listen to the messages coming from stations on the other side of the Atlantic by using a receiving circuit of which the receptive element is a small coil of wire, three or four feet square. Thus, so far as receiving goes, it is possible to intercept practically all the great stations on one half of the globe by means of apparatus contained wholly in one room, or even in a cupboard. This does not mean that the use of an antenna for reception is abolished; on the contrary, when these highly magnifying methods are put into operation with large antennæ for the purposes of reception, the range over which signals can be received is extended very far beyond what it was in 1913, and, in consequence, it is possible, under reasonably good weather conditions, to receive at the antipodes the signals from a modern high-power station. In accomplishing this the magnifications in use amount to several hundred-thousand-fold. All this is the work of a thing which looks like an ordinary electric light bulb with a few extra pieces of metal in it—the three-electrode tube. This is not all the story, for, when the tube is made in large sizes, it can be used for producing alternating current of high frequency and of considerable power, and then it can be employed for transmitting electric waves. Moreover, by giving another aspect to its functions, the triode can be used for modulating the alternating current just spoken of, and so for impressing upon the waves the human voice. In this way speech has been transmitted freely across the Atlantic, being received, it need hardly be said, at the distant end by the aid of other of the protean properties of the ubiquitous three-electrode tube.

In passing, it is worth remarking that the process of thermionic evaporation is really a method of obtaining electricity from matter without the use of moving parts—that is, without machinery. Possibly it may lead to the long-sought-for method of obtaining electricity and power direct from fuel without steam boilers or engines or dynamos. In other words, the electric engines of the future may be based upon thermionic processes deriving their energy direct from coal. Before that time comes, substances may have been discovered from which the emission of electricity takes place more easily than it does from the refractory metals we most frequently employ in the filaments of three-electrode tubes. It is known already, for instance, that some of the earthy oxides are greatly superior to platinum or tungsten in this property of emission of electricity. A new condition

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of matter, or a new substance, may be involved here and awaiting investigation.

The development of the three-electrode tube from fundamental ideas can be traced a long way back. The use of auxiliary electrodes in order to influence the current passing between two main electrodes in a vacuum tube has often been proposed, and had to some extent been applied before the method of obtaining the electrons from a hot filament was introduced into wireless telegraphy. Even after the use of the third electrode had been combined with the use of a thermal source of electrons many minds and hands were needed, and many years elapsed before the researchers themselves realised how useful the contrivance was destined to become.

As has already been hinted, the three-electrode tube (which will in future be called briefly a "triode") has found applications in every branch of wireless telegraphy and telephony, as will be shown shortly. There is no doubt it will prove equally useful in other branches of applied electricity and also as a tool in the hands of the experimental physicist. For instance, one fundamental property of the triode is that an electrical influence in one circuit may, by acting upon the control electrode, be made to exert effects in another circuit without suffering appreciable reaction; which implies that practically no energy is absorbed by the control electrode, not even so much as would be used up in setting a galvanometer needle into motion. This property alone should make the instrument welcome as a tool in the physical laboratory.

Then, again, the combination of triodes in cascade so as to obtain very large magnification opens up new regions of research by aid of the ear, and sanguine persons even anticipate that we shall some day hear the clatter of the collision of individual atoms with one another. Besides this, there is the fact that the triode provides a very convenient means of generating oscillations of exceedingly high frequency, which opens illimitable fields of measurement upon the properties of matter and of electric waves.

Amplifiers using several triodes have been made in thousands during the war for use in earth telegraphy, in submarine listening, in telegraphy by certain invisible rays or by electromagnetic induction, as well as for use in wireless telegraph stations. Besides this, it is possible to build amplifiers for work at ten or twenty vibrations per second, using a vibration galvanometer as the indicating instrument. The sensitiveness of some apparatus developed in my laboratory during the war is such that it is possible to detect with certainty alternating current corresponding to one ten-thousand-millionth part of a volt at the input side. Magnifications of the order twenty thousand times are here involved. This tempts one to revive old dreams of trans-oceanic telegraphy by means of alternating currents delivered into the sea at the ends of long cables. Calculation shows that by aid of a cable fifty miles long on each side of the Atlantic Ocean, capable of delivering about forty amperes alternating current of frequency 20 $\sim$, telegraphic communication ought to be possible by aid of the three-electrode tube.

Perhaps the uniform generation of electrical oscillations in a circuit by aid of a triode is one of the most striking and fascinating of its applications.

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Not that there is anything visible, for, in fact, rather special apparatus is required to tell that oscillation is taking place, and the interest excited is, therefore, scientific.

It is usually found on analysing an oscillator that the maintenance of the oscillations largely depends upon the interaction of two portions of the circuit on each other. If it be arranged that these two parts can be separated so as to interact less strongly the oscillation becomes weaker. There is a critical setting where oscillations are just not maintained, and the system is poised in suspense, so to speak. When it is in this condition, a very feeble stimulus, if properly timed, can provoke the system into vibration; the resulting display is energetic to an extent out of all proportion to the initial stimulus. Evidently enormous magnification is possible in this manner with a single triode. Its most important application is in wireless telegraphy, and many ships are equipped with this type of receiver. By its aid spark signals can be read at distances that are amazing compared with the old records.

If any one tries the experiment just indicated to find what order of magnification is obtained by the sub-generative method, he will discover that, on passing gradually from this adjustment to the oscillating condition, other phenomena arise. If the incoming oscillations which he is trying to magnify are unceasing and uniform, and of nearly the same audible frequency as that natural to the oscillator, he will find that a throbbing appears in the formerly steady musical note of the telephone. The throb appears only when the input current is really being introduced into the oscillating system, and is more marked the greater the original strength of the current that is to be magnified; but the input necessary to produce a perceptible amount of throbbing is exceedingly small. It would seem that the input current, when it reaches the grid, becomes magnified, first by the more ordinary processes of the triode, and then combines with the local oscillations to produce what the musician calls " beats," and then the beats are themselves magnified by circuits of the triode.

As carried out in wireless, the operator at a receiving station sets his apparatus near the wave length he desires to receive, and then causes his triode to sustain his circuits in oscillation. The waves from the distant station, acting upon his antenna, produce minute currents in the antenna which are transformed so as to apply an electromotive force to the grid of the triode. The result is an audible note in the operator's telephone each time the key of the transmitting station is depressed, provided, of course, the frequency of the receiver is near enough to that of the incoming waves. He can adjust the local frequency at will, and make it very near to the waves or very different from them; these adjustments alter the pitch of the beat note, and he chooses the more agreeable and efficient setting for the reception in hand. This process of receiving continuous wave signals on an oscillating circuit is called autoheterodyne or, sometimes, endodyne reception. Circuits can be designed in which a change of capacity of about one-thousandth part of the electrostatic unit can be detected; and in such circuits the change of capacity produced, for instance, by substituting coal gas for air in a condenser, is measurable with facility.

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C. L. FORTESCUE.—The interest in the thermionic valve lies partly in its application and partly in the underlying physics of its action.

The application is mostly concerned with the use of the valve as a finished article in combination with various electrical circuits. The problems encountered are similar to, or often merely variations of, the ordinary problems of electrical engineering, and, as such, are essentially matters for discussion at the meetings of Section G of the Association. When the engineer begins his work, the valve is a piece of electrical apparatus having certain definite electrical properties which it is his duty to make use of to the best effect.

To the physicist, however, the main interest lies in the valve itself, and to a large extent the keenness of this interest is due to the fact that there is no widely used piece of electrical apparatus depending so directly on the most recent research work on the structure of matter. It is probable that there is no other sphere where research work has had such a combination of immediate practical value and intense theoretical interest.

Several papers dealing with the application are being read before the Association. In these papers the advantages of the valves for the various purposes for which they are used are fully explained. Results are obtainable by means of the valves which cannot be obtained by any other device—or, at any rate, not with equal facility. It must not be assumed, however, that the valve has reached finality; that further improvement and development is not to be expected. This is very far from being the case. The valve is, in fact, still in childhood, a somewhat precocious childhood possibly, but certainly little more than that.

At the moment the popular cry is for Research and more Research. Research of the organised and industrial nature; and Research of the unorganised and spasmodic type, as carried out by the inspired genius.

In the valve there are fields of research for both these types, fields which are possibly more of interest to the physicist in consequence of the new information which may be forthcoming than in consequence of any improvement to the valves that may be effected. It seems highly appropriate, therefore, to consider before this Section some of the possible lines which this research might take.

The filament of the valve, being the source of free electrons upon which the whole action depends, may reasonably be the first part to be dealt with. As far as the available information goes at present, the process of emitting free electrons appears to be somewhat as follows:—The filament is a conductor, and moving in the interstices between the atoms are a large number of electrons which are free in the sense that they can move with relatively little constraint amongst the atoms, but are not free in the sense that they can be dragged away from the conductor either in air or in a vacuum with electric fields of ordinary magnitude. The fields in the inter-atomic spaces are very intense, and although they more or less balance out inside the conductor—so allowing the electrons to move along the conductor with some freedom under weak fields—they effectively prevent electrons from being drawn away from the boundary surfaces. The average kinetic energy of

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the electrons is apparently the same as that of a molecule of a gas at the same temperature. As the temperature is increased the mean energy increases according to the usual gaseous laws. Some electrons at some periods have, momentarily, energy far in excess of this average. Hence, as the temperature is increased, a state is reached where an appreciable proportion of the electrons near the surface become possessed of sufficient energy to break away from the attractions of the surface atoms, and so become free electrons in the sense that they can be drawn away by the application of electric fields of quite ordinary magnitude. At any particular temperature it is probable that the distribution of energy is the usual Maxwell distribution. So if a definite energy is required to enable the electrons to break away from the surface, it follows that, as the temperature is raised, the number of electrons escaping increases very rapidly. The full theoretical treatment may be found in Professor O. W. Richardson's monograph, "The Emission of Electricity from Hot Bodies."

In practice, the hot conductor now most largely used is a filament of tungsten heated by passing a current through it, but it is by no means an ideal source. It is very liable to damage during the exhausting process, and it is highly inefficient. The electrons that break through the boundary appear to require energy corresponding to about four and a half volts. Now, with an ordinary filament, an optimistic estimate of the watts required to heat the filament for an emission of one ampere of free electrons is 100. This ampere of electrons absorbs energy at the rate of about four and a half watts, the remaining ninety-five and a half being radiated as ether waves or conducted down the filament supports—principally the former with the large valves. The efficiency of the filament is thus about $4\frac{1}{2}$ per cent., and it immediately becomes a matter for consideration as to whether this cannot be improved upon.

Numerous possibilities suggest themselves; first and foremost, is tungsten the best material? It is well known that surface contamination of the filaments will reduce the emission for a given temperature. On the other hand, the addition of certain oxides similar to those used in the Nernst filament will greatly increase the emission. Is it, therefore, not possible to find some alloy of tungsten, or some mixture of tungsten and oxides, having an efficiency far above that of the filaments now in use? Possibly some entirely different substance could be used where the energy required for an electron to break through the boundary is much less than the four and a half volts of tungsten. It is well known that a lime-coated filament will give, for a time, a large emission at a surface temperature in the neighbourhood of 1,000° C., whereas, for tungsten to give the same emission, a temperature in the neighbourhood of 2,000° C. is required. Could not the improvement be carried further with careful investigation?

The oxide-coated filaments used up to date are fragile, and more liable to damage during exhaust than are the tungsten ones. The cause of this damage is, undoubtedly, the bombardment of the surface by positive gaseous ions. What is the nature of this damage? Is it purely mechanical, consisting of atoms or groups of atoms being, as it were, chipped off? Apparently

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this is the case, and apparently the conditions are unstable in that the chipped area emits more freely, and so attracts more positive ions. Cannot this damage due to bombardment be overcome ?

Many of the lime-coated platinum filaments lose their power of emitting electrons after a time. There is some evidence of the surface developing a cracked appearance like that of dried mud. The surface layers, though at a high temperature, have probably little of the heating current passing through them when the cracks have developed. Has this anything to do with the falling-off of the emission, or is the deterioration connected with impurities in the lime, which are gradually evaporated away or broken up chemically ?

Then, again, if research shows that the energy limit cannot be very much reduced, is it possible to use still higher temperatures ? The efficiency of the tungsten filament increases with increase of temperature, owing to the increase of the number of electrons possessing sufficient energy to break away being more rapid than the increase of the energy radiated. Presumably, the same holds for all substances. If a higher temperature is to be used, carbon seems to be the only possibility. That being so, is it impossible that means should be devised of making a carbon filament that does not lose its adhesion at temperatures higher than those at which tungsten is used at present ? If such a filament could be constructed, it would revolutionise the lamp industry !

The use of a filament heated by passing a current through it is in itself objectionable in that it means that different parts of the emitting surface are at different potentials. This difference of potential may have an appreciable effect on the characteristic curves of the small low-voltage valves. Some form of separate heating suggests itself, but the difficulties to be overcome in order to secure a high efficiency and a cheap construction are very great.

Any method of freeing the electrons by thermal agitation has the further disadvantage that the electrons are emitted with varying velocities. This causes a rounding off of the corners of the characteristic curves, and materially affects the action of the valves when used for limiting or as sensitive rectifying detectors.

Possibly there may be alternatives to the method of thermal agitation.

Photo-electric methods suggest themselves, but at present the emission currents are small, and the over-all efficiency is much less than that of the thermal method. Moreover, the electrons are still, apparently, emitted with varying velocities.

Finally, there is the question, " If the electrons have to be given energy corresponding to from two to five volts, is it in any way possible to give them this energy without so accelerating them that a far greater amount of energy is radiated ? " That is to say, is not the process a fundamentally inefficient one ; at any rate, at the temperatures at which the materials known to-day can be used. It would appear that this problem should be amenable to mathematical treatment.

Passing on to the grid electrode, several questions present themselves.

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An extremely important one in the small receiving valves is that of the contact potential between filament and grid. It is believed that this point is being touched upon more fully by others taking part in this discussion.

Then there is the combined mathematical and mechanical question of the best form of the grid electrode. Numerous forms of this electrode have been described in patent specifications and elsewhere; notably in a specification of the Western Electric Company.

Some of these forms are possibly amenable to approximate mathematical treatment, and, if they have the additional virtue of mechanical simplicity, the results would be of value.

At the positive electrode the outstanding problem is that of the occluded gas. In point of fact, it is not the positive electrode only that is involved. During exhaustion, and when in use, gas may be liberated from any of the electrodes or from the inner surface of the containing envelope. With a high-vacuum high-voltage valve, where the gas pressures are in the neighbourhood of one ten-thousandth of a millimetre of mercury or less, a very minute quantity of gas will lead to appreciable ionisation effects, with the consequent instability and rapid destruction of the filament.

The term " occlusion " is used to describe the various ways in which gases may be retained in matter in the liquid and solid state. In the present instance the interest lies in the retention of the gas in the solids. Three clearly distinguishable processes appear to be involved, viz. :—

(*a*) There may be minute blowholes, or the remains of blowholes, where some gas has been entrapped when the solid last passed from the liquid to the solid state. This gas might have come from the atmosphere of the furnace, but more probably it was gas which was originally in solution in the liquid.

(*b*) The solid may consist in part of actual chemical compounds which decompose and liberate gas under heat treatment or under electron bombardment.

(*c*) There are the allied phenomena of surface absorption, solid solution in the crystals of the solids, and the retention of the gases in the amorphous intercrystalline layers.

The first two of these three possibilities are not, probably, of serious import. Preliminary heat and vacuum treatment will remove most of the gas ever likely to be liberated in these ways from the metal portions of the valves, and there does not seem to be any evidence to show that gas is liberated from the glass from either of these causes. It is the phenomena of the third category that present the difficulties.

The problem is either to remove these gases or to treat the surface so that the gas cannot escape whilst the valve is in use.

The present procedure is of the sledge-hammer type, and merely consists of exposing the valve to a higher temperature and a heavier bombardment whilst the valve is connected to the pump than it will ever experience in actual use. The gas coming out under these conditions is pumped away,

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and it is piously hoped that so long as the working conditions are less stringent no further gas will be evolved.

Presumably the absorbed surface layer will be removed by this treatment. The extent to which the gas is removed from the crystals and the inter-crystalline layers is doubtful. Presumably it is a question of time. If so, *i.e.*, if diffusion in the solid is appreciable, why does not some of this gas find its way to the outer surface, if an exhausted valve is left cold for, say, a month? Valves are occasionally observed to "go soft" if left in this way. Usually this is attributed to a minute leak, but there is no conclusive proof that this is the case. An examination of the spectrum of the gas in such a valve should settle this point, but no such examination appears to have been carried out up to date. It is well known that if the gas has been thoroughly removed from the electrodes of a valve, and if air is readmitted, then gas is reabsorbed by the electrodes. But unless the electrodes have been re-exposed to the air for a lengthy period, the absorbed gas is quite easily removed. Presumably it is the outer absorption layer that is involved in this case. But the question immediately arises, "For how long can the metal be exposed before the gas becomes difficult to remove again?"

The examination of the gases given out after the exhaustion was completed is a matter of intense general interest to physicists, and has brought out certain results which require a good deal of explaining. Two methods have been used, viz.:—

(1) Spectrum analysis. The valve was overloaded and the "blue glow" examined by means of a spectroscope. Many characteristic lines were observed, and many gases, such as Ar and CO, were clearly identified. Some of the spectra were, however, unusual.

(2) Ionisation potential. The grid and the positive electrode were connected together, and the voltage between them and the filament—the latter being negative—was gradually raised, careful observation of the current being made. The curves of current and voltage were then plotted. These curves follow Langmuir's 3/2 power law up to certain clearly defined points where ionisation sets in. These points are indications of the nature of the gas present. But the voltages at which ionisation sets in are quite different from the usually accepted ionisation voltages. One gas has not yet been identified, and still goes by the name of "electrode gas."

It is hoped that others taking part in this discussion will enter into this question more fully. Why are the spectra unusual? Why are the ionisation potentials abnormal? What is the "electrode gas"?

Many interesting phenomena are observed with the traces of residual gases always present even in the hardest of tubes. After running for some time with a given electron current to the positive electrode and a given voltage, a steady value for the pressure of the residual gas may be reached. If now the voltage is increased, but not sufficiently to overheat the positive electrode, the tube will harden, *i.e.*, some of the residual gas will be absorbed. On the other hand, if the voltage is reduced, and particularly if the filament is

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simply heated without any voltage being applied to the positive electrode, the amount of residual gas will increase.

These effects are well known to radiologists, and various suggestions are put forward in explanation. But from the point of view of the development of the high-power valves, the whole problem requires careful investigation.

The fact that an increasing voltage at the positive electrode hardens the valve leads to the conclusion that the effects are due to the action of the ionised gas. At these voltages the ions are positive, and their observed disappearance must be due to their being driven into the hot filament, or into the walls of the containing vessel. If they are driven into the filament, how are they retained with the filament at 2,000° C. ? Is any chemical action involved, or is it the same process as the occlusion in the positive electrode ? Or is it only the walls of the containing vessel that absorb the ions ?

A suggestion has been put forward by Dr. G. B. Bryan, of the Physics Laboratory, at R.N. College, Greenwich, that the occlusion of the gases and the emission of positive ions from metallic surfaces at moderate temperatures are closely related. He visualises the process as follows: Some proportion of the gas to which the electrodes are exposed will probably be ionised hydrogen. A positive hydrogen ion is a very small heavy projectile with considerable powers of penetration. On striking the surface of a solid it will pass through the outer surface and pick up an electron, so becoming neutral. Now, however, it is a large body entrapped in among the atoms of the metal and unable to escape under ordinary conditions. But at moderate temperatures the electrons may be shed again, and the positive ion, being no longer encumbered by the outlying electron, can escape, so constituting the positive emission. One peculiar fact has frequently been observed by Dr. Bryan when exhausting a valve, viz., that a small liberation of occluded gas will give rise to a greater tendency to arcing than the introduction of a much greater quantity of ordinary air. If the gas liberated from the electrodes is already ionised, the observation is immediately explained.

This theory is a very interesting one, and is one on which some light could be thrown by the entire removal of all traces of hydrogen. At present, however, it has never seemed possible to do this, as such extremely small quantities are involved; and possibly other ionised gases may be entrapped in the same way. If it is the outer electron that is lost, this would seem to be quite possible.

Many interesting questions arise in connection with the outer envelope. Glass is almost universally used owing to the fact that it is the only material combining high insulating properties with ease of making vacuum-tight joints with conducting wires or strips. But glass has many disadvantages, particularly for the large power valves. It is a brittle material liable to failure under mechanical shock. But worse than that is the liability to cracking when subjected to change of temperature.

Again, like metals, glass has the property of occluding large quantities of gas, which it gives up when heated. This has to be eliminated as far as possible, by "cooking" during the exhausting process. For small valves

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not liable to appreciable heating in use this presents no serious difficulties; but with high-power valves, where the bulb gets really hot when in use, there is always the risk of more gas being liberated.

The relatively low temperature at which glass of the ordinary kind softens makes it impossible to heat up the metal electrodes by external means to the temperature necessary for the removal from them of the occluded gas.

With certain kinds of glass, too, slight chemical action not infrequently takes place at the seals when subjected to high temperatures, which may lead to the seals ceasing to be vacuum tight.

Finally, a disadvantage with glass for use with power valves where the positive electrode is at a bright red or yellow heat is that it is opaque to the infra-red radiation. If it would allow this energy to pass through, the heating of the bulb could be much reduced and the size and expense would be correspondingly less.

One obvious alternative to glass is fused silica. The trouble of cracking due to temperature change does not exist. There is no difficulty, apparently, in working up to the high temperatures. The great problem of sealing in the conducting wires remains, however, an uncertainty. Many methods have been suggested, but, as far as is known, none of them have been used on a large scale with high vacuum apparatus subjected to considerable changes of temperature.

De Forest, in an American patent specification (No. 100959/1917), has described a valve made up of a double metallic container, with mercury to assist in securing vacuum-tight joints. With this arrangement the leads to the grid and filament electrodes are thoroughly insulated from the outer metallic container, which is used as the positive electrode.

Here, again, is the difficulty of the vacuum-tight joint. At high power the smallest trace of mercury vapour leads to disintegration of the filament from the heavy bombardment with positive mercury ions.

If a really flexible cement could be devised that would secure a vacuum-tight joint between two materials of different co-efficients of expansion, and which would withstand temperatures up to, say, 300° C., a design of power valve on the general lines of De Forest's patent would be possible. Once this was accomplished, and once the difficulty of occluded gas was overcome, all limits to the output of the transmitting valves used for wireless telegraphy and telephony, other than that of power available, would be removed. No longer would it be necessary to put up with the unsatisfactory and tricky arcs where high powers are required, and a valve giving an output of 500 k.w. would become quite feasible. It is interesting to note that such a valve would require a free-electron emission of some thirty or forty amperes—and it is only a few months ago that the habit of measuring free-electron currents in microamperes was given up!

All the foregoing remarks have presupposed a valve of the same general type as that now in existence. The function of a valve is essentially that of a relay, and its fundamental advantage lies in the fact that its moving parts consist of free electrons. The three-electrode tube is one way of making use of the electron stream so as to get the relay action. Is it the

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only way? In Hull's dynatron the electron stream is used in a different manner, and, for some purposes, may have advantages over the ordinary three-electrode type. This is one alternative. Are there no others?

With the power valves the present method of operation gives an efficiency —neglecting the filament watts—of about 75 per cent. under the best conditions. Is there no way of improving this?

B. S. GOSSLING.—A considerable number of physical phenomena, besides the actual thermionic emission and the effects of the mutual repulsion of the emitted electrons, are observed to enter into the action of the valve. These include the Maxwell distribution of velocities amongst the electrons, the contact potential between the filament and the grid, the composite electric field produced near the filament by the grid and anode, and by the difference of potential between the two ends of the filament, and also the orbits described by the electrons in the neighbourhood of the grid wires. The pressure of the residual gas present is usually reduced to a point (*e.g.*, 0·0001 mm.) where the ionisation produces little effect on the space current.

Test observations on very large numbers of valves were made during the war, the final rate of production of valves having been about 500,000 per annum. These observations indicate the range of probable variation of the various factors, confirm earlier purely scientific work, and provide a basis for further investigations.

In the valves handling higher powers the important phenomena are few and simple. Complete prior information, theoretical and numerical, as to these being available, the necessity for experiment was in large measure avoided and development much accelerated.

Dr. WHIDDINGTON opened his remarks by alluding to the difficulty of adding much in a few minutes to what had already been given so admirably by the three previous speeches. He thought, however, that it might be useful to draw attention to a few of the possibilities of the valve in the physical laboratory. Taking, for example, the well-known typical oscillating circuit alluded to by Professor Eccles, it could be shown, theoretically, that it was only when the mutual induction M between grid and anode coils was greater than $\frac{1}{k}\left(\frac{L}{\rho} + RC\right)$ that the oscillations of period $2\pi\sqrt{LC}$, natural to the circuit, were initiated and sustained.

In this formula L, C and R were the usual constants of the periodic circuit, ρ was the valve resistance, and k the amplification factor of the valve. This gives at once a method of determining the value of M between two coils, for if one is connected between grid and filament, the other between anode and filament, and a condenser, C, placed across the anode coil and adjusted till oscillations are just not sustained, then (very nearly) $M = \frac{RC}{k}$. Captain Turner had produced a relay valve on this principle.

M was, in his arrangement, just less than $\frac{RC}{k}$. A signal incident on the

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system upset the balance and produced oscillations, thereby slightly increasing k and making the oscillations permanent; the relay, in fact, was not self-restoring, and had to be restored to quiescence mechanically, as, for example, by a Post-Office relay in the anode circuit. But from the above formula it is clear that, if a wire of positive temperature resistance coefficient be included in the oscillating circuit, then, as soon as oscillations are produced, the wire gets hot and its resistance rises, if a suitable choice has been made, to such a value as to extinguish the oscillations and make the relay self-restoring.

Professor Eccles had pointed out the extreme sensitiveness of heterodyne reception at wireless frequencies, giving as an example the effect of passing coal gas in place of air between the plates of the air condenser used in his experiments. Dr. Whiddington said that in addition he had demonstrated the change of resistance with temperature of conducting wires, the conductivity of flames, the permeability of liquids, etc., and he thought that many interesting quantitative investigations along these lines could be usefully carried out.

Sir OLIVER LODGE and *Dr. W. MAKOWER* briefly discussed the use of radioactive processes in valves; and *Mr. S. G. BROWN* referred to recent experiments with lime-coated cathodes.

Wireless in the Royal Flying Corps.

By MAJOR T. VINCENT SMITH, R.A.F., M.C., M.I.E.E.

This paper dealt with wireless in what was the military wing of the R.F.C. on the Western Front during the first three years of the war, and detailed the history of this work up to the time of the amalgamation of the R.N.A.S. and R.F.C. into the Royal Air Force.

It showed the state of knowledge at the beginning of the war, and the gradual progress made in the building up of an immense organisation. The experiences of early days, the difficulties which arose, and how they were overcome were described in detail. Improvements in apparatus, methods, organisation, and their effect upon operations were shown, and the technical means whereby the enemy was beaten were discussed.

The important work of the R.F.C. in co-operation with artillery, infantry and cavalry would have been practically impossible without wireless. The introduction of thermionic valves for reception, transmission, inter-aeroplane telephony and directional wireless were touched upon, though the war ended before their influence had time seriously to effect the final operations.

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The story of wireless in the R.F.C. is a collection of details, each one small in itself, but the combined whole shows how the many difficulties inseparable from an ever-increasing demand were overcome in a way which earned the respect of the enemy.

A Wireless Method of Measuring the Ratio e/m.

By R. WHIDDINGTON, M.A., D.Sc.

This paper deals with the use of a valve to measure the ratio of charge to mass for electrons and ions. It will be given in full in our next issue.

Diffraction of Electric Waves.

By PROFESSOR G. N. WATSON, F.R.S.

This paper will be dealt with in the November issue of the Radio Review.

SECTION G.

Directional Wireless, with Special Reference to Aircraft.

By CAPTAIN J. ROBINSON, R.A.F., M.Sc.

This paper, read before Section G of the British Association Meeting at Bournemouth, is merely a brief summary of more technical papers by the same author, which we are publishing in full in succeeding issues of the Radio Review.

The following is an abstract of the paper as presented at the meeting :—

(1) The ordinary methods of navigation which are used for ships at sea are not sufficient for aircraft, as the conditions as regards drift are of an entirely different order. It is thus necessary to use some other means for determining position in the air. Drift is of a very large magnitude in the air, and by night, or in fogs, it is very often impossible to apply dead reckoning methods. The use of wireless bearings is the most hopeful method of progress, as bearings can be obtained with considerable accuracy.

The systems for determining bearings that were known at the beginning of the war were :—

(*a*) The single coil method. When such a coil is rotated about a vertical axis the intensity of the wireless signal varies from zero to maximum, being zero when the plane of the coil is at right angles to the direction of the incoming waves.

(*b*) The Bellini-Tosi system. This system used two fixed loop-aerials at right angles to each other, the moving part being a small coil rotating between two coils at right angles, which are in the circuits of the two fixed aerials.

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(*c*) The Telefunken clock.

(2) There are two distinct methods of employing wireless bearings in order to determine position :—

(*a*) By the first method the machine transmits, and the direction-finding stations are on the ground. Each direction-finding station finds the bearing on the moving object and communicates its bearing to a central station. There the position of the moving object is worked out from the various bearings and re-transmitted to it.

(*b*) By the second method the moving object, either aircraft or ship, has its own direction-finding apparatus, and finds bearings on fixed transmitting stations.

As regards aircraft, method (*a*) was used largely by the Germans. This method has considerable drawbacks, the first being that, in case of war, when the aircraft transmits to ask for its position, this is also disclosed to the enemy.

Secondly, only very few aircraft can be dealt with, as a considerable amount of transmission is required for a single aircraft to find its position. In consequence it was decided to attempt to use method (*b*) in the British Air Service.

(3) Royal Air Force system. In attempting to apply direction-finding systems to aircraft it was found that considerable modifications to the known systems had to be applied. The single coil and Bellini-Tosi systems are what are called minimum systems, *i.e.*, in order to determine the bearing one finds the minimum by swinging the coil through this position until the signal is heard on both sides. On aircraft, as there is considerable extraneous noise, the region of this minimum is widened, and, in consequence, the accuracy of the system diminishes. It is necessary to use a system where signals can be heard whilst the bearing is taken. The system devised is to use two coils at right angles, which can be rotated together on a vertical axis. One coil alone is used first, and the system rotated to be somewhere near the maximum of this single coil. Then the second coil is introduced, and its effect added to or subtracted from those of the first coil. If the first coil is correctly on its maximum, then the second coil will be on its minimum, and thus there is no change of intensity on adding or subtracting the effects of this coil by a reversing switch. This method enables bearings to be taken whilst the signal is heard, and it is easy to see that it can be applied to any system which has hitherto been a minimum system. Having devised this system, there were other problems to be solved.

(*a*) One was to obtain efficient strength of signals. It was uncertain as to whether loops could be obtained of sufficient size to give loud enough signals to hear over the noise of the engine.

(*b*) The Bellini-Tosi system was considered to be too complicated, as at that time it was necessary to tune the two aerials to exactly the same frequency, and unless this system is very carefully installed fairly large errors are introduced.

(4) It was hence decided to use the rotating aerial system. This was done in two ways.

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(*a*) The wing coil system. In this case the aerials are fixed rigidly to the aeroplane, which has to be rotated in order to determine the bearing. This system is particularly useful in the case of flying towards an objective where there is a wireless station. One particular example is where a wireless station exists at the aerodrome, and the machine can thus return home by merely heading to this wireless station.

(*b*) The rotating coil system. In this case the rotating coils are placed in the fuselage, and are rotated independently of the machine. This is particularly useful on the larger type of aeroplane, and enables position to be determined whenever a sufficient number of transmitting beacon stations can be heard.

(5) Considerable difficulties had to be overcome to bring the R.A.F. system to a stage of perfection.

(*a*) The extraneous noises on an aeroplane are considerable, but, besides, there is a far greater disturbing influence in the electrical disturbance due to the magneto. This produces considerable noise in the telephones, and cannot be overcome by amplifications of signal strength. It is necessary to cut out this electrical disturbance. The cause of this disturbance was traced to the emission of very short waves by the magneto, the wave length being of the order of from five to thirty metres. It is possible to use short wave stoppers to cut out these waves, but by far the most efficient method of eliminating this disturbance is to screen the whole magneto system.

(*b*) When using the fuselage coil system it was found that corrections had to be applied for the deviation produced by the metal work of the aircraft. These corrections can be determined by swinging the aircraft in a similar way to the swinging of a ship to adjust the compass.

(6) In addition to the preceding difficulties there is another trouble in the variation of bearings produced by atmospheric influence. The extent of these variations is not large, possibly never more than about 3° when using waves of 2,000 metres and upwards. The problem of this variation is one that should be investigated at an early date. The R.A.F. system of D.F. gives means for recording these variations very accurately. The sensitiveness of this system is under control, and depends on the ratio of the area-turns of the two coils. It is possible to design coils so that the system is sensitive to $\frac{1}{4}$°. This is the case when the minimum coil has its area-turns about eight times those of the maximum coil. With such a system it is easy to conceive an automatic arrangement, so that the variations in bearings can be automatically recorded.

(7) Excellent results have been obtained with the R.A.F. system of wireless navigation. A large number of flights have been made, and it has been found that the mean error of bearing is $1\frac{3}{4}$° when using beacon stations whose distance varies from 20 to 500 miles. Under these circumstances, when three beacon stations are available, the mean error in determination of position was found to be seven miles.

Flights have been made purely by wireless navigation. One particular flight was made from Biggin Hill to Paris, and back from Paris to Brighton. In both of these flights the machine was above the clouds most of the time.

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Position was determined by wireless bearings, and the course was set or altered from these determinations. The navigator was in a position so that he could not look out of the aeroplane, and he was able to determine the force and direction of the wind and to forecast the time of arrival at his destination within two minutes.

The Three-Electrode Thermionic Valve as an Alternating Current Generator.

By PROFESSOR C. L. FORTESCUE.

A Method of Using Two Triode Valves in Parallel for Generating Oscillations.

By W. H. ECCLES, D.Sc., and F. W. JORDAN, B.Sc.

A Trigger Relay Utilising Three-Electrode Thermionic Vacuum Tubes.

By W. H. ECCLES, D.Sc., and F. W. JORDAN, B.Sc.

The above papers will be dealt with in the November issue.

The Wireless Society of London.

We understand that the above Society shortly hopes to resume its activities. A committee meeting, under the presidency of Mr. A. A. Campbell Swinton, F.R.S., was held on July 24th, and further preliminary meetings are now being arranged. The Society is open to all interested in the study and furtherance of wireless telegraphy. The new secretary is Mr. L. McMichael, 30, West End Lane, West Hampstead, N.W. 6.

The services of the Advisory Committee of this Society are again being accepted by the Post Office in connection with the issue of Experimental Licences for Radio work.

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Review of Radio Literature

1. Abstracts of Articles.

NOTE.—*It is intended to devote the space in this section of the* RADIO REVIEW *to as complete a review as possible of the published literature of radiotelegraphy and telephony, and kindred matters. The more important of these papers and articles will be given in abstract, while, for the remainder, references will be given, accompanied by one or two lines to indicate the contents of the article. In this way it is hoped to obtain a complete monthly record of the progress of the science, and of the latest developments and inventions relating thereto, that should be of considerable value to all research workers and students of the subject.*

1. ON THE ABSOLUTE MEASUREMENT OF THE TIME PERIOD OF H.F. OSCILLATIONS. By H. Abraham and E. Bloch. (*Comptes Rendus*, 168, p. 1105, June, 1919. *Rev. Gen. de l'Elec.*, 5, p. 855, Abstract.)

The precise determination of the wave length of high frequency electric oscillations is of great importance for the calibration of wavemeters and for all H.F. measurements. The use of standard inductances and condensers to construct a circuit of known wave length does not permit of an accuracy greater than 1 per cent. The method described by the author involves the direct comparison with a tuning fork standardised by comparison with a standard clock. A source of electric oscillations rich in harmonics is then adjusted (by the method of beats) to have the same fundamental frequency as the fork, while one of its higher harmonics is then compared with the high frequency oscillations. Special arrangements of three electrode valves are used for the comparison source of oscillations, giving harmonics up to 200—300 times the fundamental frequency. The accuracy obtainable is claimed to be closer than 0·1 per cent.

2. ELECTRICAL OSCILLATIONS IN ANTENNAS AND INDUCTANCE COILS. By J. M. Miller. (*Proceedings Inst. Radio Engineers*, 7, pp. 299—326, June, 1919.)

The author applies the theory of circuits having uniformly distributed electrical characteristics to the problem of the electrical oscillations in aerials and inductance coils. A number of errors in the interpretation of previous applications of the theory are pointed out, and the effective inductance, capacity and resistance of aerials are calculated, with and without series loading coils or condensers. Putting C_1 = capacity of aerial per unit length, L_1 = inductance per unit length, R_1 = resistance per unit length, l = length, $C_o = C_1 l$, $L_o = L_1 l$, and $R_o = R_1 l$, it is shown that the effective static or

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low frequency resistance, inductance and capacity are given respectively by $R_e = \frac{R_o}{3}$; $L_e = \frac{L_o}{3}$; $C_e = C_o$. At the frequency of the fundamental of the aerial these become $R_e = \frac{R_o}{2}$; $L_e = \frac{L_o}{2}$; $C_e = \frac{8}{\pi^2} C_o$.

It is further shown that for most practical cases the aerial can be represented by its "static" inductance $\frac{L_o}{3}$, with its "static" capacity C_o in series, and the frequency of the oscillations with a loading coil L in the lead-in can be computed by the ordinary formula applicable to circuits with lumped constants, *i.e.*, the wave length in metres is given by $\lambda = 1885\sqrt{\left(L + \frac{L_o}{3}\right)C_o}$. When L/L_o is greater than 0·5, the error obtained by the use of the above approximation is less than $1\frac{3}{4}$ per cent., while in the extreme case of no loading coil in series the error rises to 10 per cent. Similarly, for an inductance coil it is shown that the effective "self-capacity" $C_e = \frac{C_o}{3}$, so that the wave length of oscillation of the coil with a capacity C across its terminals is given by $\lambda = 1885\sqrt{L_o\left(C + \frac{C_o}{3}\right)}$.

The frequency variation of the effective resistance of an aerial is then considered. Measurements are described and curves given, which indicate that antenna resistance is largely due to imperfect dielectrics in the field of the aerial, and emphasis is placed on the necessity of avoiding such dielectrics in regions of strong electrostatic field.

3. QUANTITATIVE EXPERIMENTS WITH COIL ANTENNÆ IN RADIOTELEGRAPHY. By L. W. Austin. (*Journal of the Washington Academy of Sciences*, 9, p. 335, June, 1919.)

Theoretical transmission formulæ for frame aerials are given in this paper. Fundamentally the following formula is assumed for ordinary aerial to aerial transmission:

$$I_r = 120\pi \frac{I_s h_s h_r}{\lambda d R} \text{ (meters and ohms).}$$

The replacement of either or both aerials by a frame necessitates the substitution of the expression $N \cdot H \cdot 2\pi \frac{L}{\lambda} \cos\theta$ for the height of the aerial in the above formula.

Let N = number of turns on frame, H = height of frame, L = length, λ = wave length, θ = angle between plane of coil and the direction of the incoming waves. The following formulæ are then derived. Frame sending aerial to antenna at receiver:

$$I_r = 2369 \frac{I_s N_s H_s L_s h_r}{\lambda^2 d R} \cos\theta_s.$$

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Antenna sending and frame receiving:

$$I_r = 2369 \frac{I_s h_s N_r H_r L_r}{\lambda^2 d R} \cos \theta_r.$$

Frame sending and frame receiving:

$$I_r = 14880 \frac{I_s H_s N_s L_s H_r L_r N_r}{\lambda^3 d R} \cos \theta_s \cos \theta_r.$$

If $\theta = 0$, the "effective height" of an ordinary aerial equivalent to the frame is:

$$h = 2\pi \frac{\text{Area} \times \text{Turns}}{\lambda}.$$

Experiments are mentioned showing measurements ranging up to 24 per cent. from the calculated figures—these errors are partly due to the action of the frame and its leads as an ordinary plain receiving aerial. A very good agreement is found between the formula and the measurements when sending on the frame aerial and receiving on an antenna.

4. Radio Transmission Formulæ for Antenna and Coil Aerials. By J. H. Dellinger. (*Journal, Franklin Institute*, 188, pp. 95—96, July, 1919. *Telegraph and Telephone Age*, p. 370, August 1st, 1919, Abstract.)

Transmission formulæ are given applicable to communication with ordinary and frame aerials. Originally derived from theoretical considerations, they have been verified experimentally in a number of cases investigated by the U.S. Signal Corps. A flat-top type of aerial is considered, and a rectangular frame.

Antenna to antenna:

$$I_r = \frac{188\, h_s h_r I_s}{R \lambda d}.$$

Antenna to frame coil:

$$I_r = \frac{1884\, h_s h_r N_r I_s}{R \lambda^2 d}.$$

Frame to antenna:

$$I_r = \frac{1884\, h_s l_s h_r N_s I_s}{R \lambda^2 d}.$$

Frame to frame:

$$I_r = \frac{7450\, h_s l_s h_r l_r N_s N_r I_s}{R \lambda^3 d}.$$

Where h = Height of aerial or frame; l = Horizontal length; N = Number of turns of wire on frame; I = Current — amperes; λ = Wave length; d = Distance apart of transmitter and receiver; R = Resistance of receiving aerial circuit.

Subscripts s and r refer to sending and receiving respectively.

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5. SENSITIVE APPARATUS FOR THE MEASUREMENT OF ALTERNATING CURRENTS. By H. Abraham, E. Bloch and L. Bloch. (*Comptes Rendus*, 169, pp. 59—62, July, 1919.)

The need of suitable apparatus for the measurements of feeble alternating currents and potentials is emphasised in this communication. An arrangement is described consisting of an indicating direct-current milli-ammeter or micro-ammeter, used in conjunction with one or two 3-electrode amplifying valves and one detecting valve. It may be used for currents of radio or low frequencies, and will indicate potentials of the order of one millivolt, while the effective resistance of the apparatus when used as a voltmeter is extremely high.

6. THE PRODUCTION AND MEASUREMENT OF SHORT CONTINUOUS ELECTROMAGNETIC WAVES. By Balth Van der Pol, D.Sc. (*Philosophical Magazine*, 38, p. 90, July, 1919.)

7. RADIO TRANSMITTING SETS ON THE N.C. TYPE SEAPLANES. (*Telegraph and Telephone Age*, pp. 330—331, July 1st, 1919. *Electrical Review*, 85, p. 233, August, 1919, Abstract.)

These 550-watt transmitting sets, as employed on the N.C. type seaplanes used for the American trans-Atlantic flight, possess some novel features.

The complete transmitter, with the exception of the sending key, and the aerial ammeter and tuning coil, is mounted in the stream-line casing enclosing the 1,000 ~ alternator (Fig. 1). The generator, of the inductor type, delivers 135—150 volts at 5,000 r.p.m., dropping to 100 volts at full load. The stator has four D.C. poles, into each of which are cut four slots for the A.C. winding. The rotor has twelve teeth, and acts as the inductor. The D.C. armature winding for exciting the field is wound in the slots between the rotor teeth. Two rotary gaps of twelve and eight teeth are mounted on the same shaft, enabling spark frequencies of 1,000 or 666 to be used as desired. The transformer has a step-up ratio of 34 : 1, and the mica dielectric oscillation circuit condenser has a capacity of 0·01 mfd. Wave lengths of 335, 375 and 425 metres may be used with a trailing wire aerial 250 feet long. A feature of the aerial tuning inductance is the provision of a copper ring to screen the magnetic field from the turn under the contact,

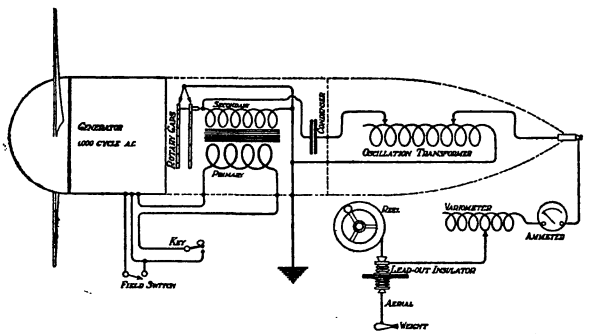

FIG. 1.

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thus preventing sparking when passing over from one turn to the next. Normal range = 300—400 miles, but the sets were heard for 1,200 miles during the trans-Atlantic flight.

8. "On the Electrical Operation and Mechanical Design of an Impulse-Excitation, Multi-Spark Group Radio Transmitter." Further discussion by S. Cohen. (*Proceedings Inst. Radio Engineers*, 7, p. 327, June, 1919.)

This additional discussion on the original paper by B. Washington with this title, deals with further experiments on impulse transmitters, and the use of tungsten-tungsten and copper-amalgamated copper electrodes in alcohol. The former gap is suitable for radiotelephony.

9. Apparatus for Producing High-Frequency Oscillations. By I. Shoenberg and Marconi's Wireless Telegraph Company. (*British Patent* 126146. May, 1918.)

With a view to utilising the qth harmonic of a high-frequency alternator, the ratio of breadth of rotor teeth to their pitch is made equal to $q/2 \times$ an odd integer greater than unity. In a case utilising the 5th harmonic, rejection circuits tuned to the fundamental and 3rd harmonic frequencies are joined in the main circuit to cut out the unwanted frequencies.

10. On the Poulsen Arc and Its Theory. Supplementary note by P. O. Pedersen. (*Proceedings Inst. Radio Engineers*, 7, pp. 293—297, June, 1919.)

A continuation of an earlier paper discussing production of sustained oscillations of the first or second types by Poulsen arcs. The effect of too strong or too weak magnetic fields is considered.

11. Electric Oscillation Generators. By N. Lea. (*British Patent* 128383. June, 1918.)

An electric oscillation generator adapted for standardising oscillatory circuits, or for use as a wave meter. An ordinary type of three-electrode-valve oscillation circuit is described, having tuned anode and untuned grid circuits, with telephones in the anode circuit. The filament battery is used to supply the anode circuit voltage, as well as for lighting the filament.

12. The Current-Voltage Characteristics of High-Voltage Thermionic Rectifiers. By C. L. Fortescue. (*Proceedings Physical Society of London*, 31, pp. 319—337, August, 1919.)

This paper deals in detail with the design of circuit arrangements for high-voltage valve rectifiers. If I_o is the direct current output current, V_o = direct current output voltage, a = fractional permissible variation in V_o (usually $< 0{\cdot}1$), θ = the phase angle of the alternating current supply when the applied alternating current voltage becomes equal to the output voltage V_o, f = frequency, C = condenser capacity required, then

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$$C = \frac{I_o}{V_o} \cdot \frac{1}{af} \cdot \frac{\pi + 2\theta}{2\pi}$$. for a single-valve rectifier, or

$$C = \frac{I_o}{V_o} \cdot \frac{1}{af} \cdot \frac{\theta}{\pi}$$ for a two-valve rectifier.

Expressions and curves are also given for the transformer current, and the efficiency of the whole arrangement.

13. Wireless Telephone Transmitters. General Electric Company (U.S.A.). (*British Patent* 127325. April, 1917.)

An arrangement of valves for wireless telephone transmission is described.

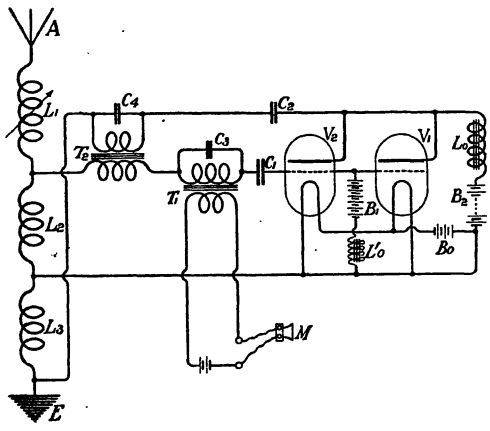

Fig. 2.

A number of valves are used in parallel, fed from common filament and anode batteries. Fig. 2 shows one connection scheme. V_1 V_2 are two oscillating valves in parallel fed from the filament battery B_o, grid battery B_1 and anode battery B_2. The oscillation circuit comprises the inductances L_2 L_3, and the aerial circuit capacity plus the valve grid-plate capacity. The transformer T_1 couples the control microphone M to the grid circuit, and T_2 provides a return coupling between the plate and grid circuits. This return coupling is for the speech frequencies only, and both transformers may have iron cores, as indicated.

14. Wireless Telephony. Société Française Radio Électrique. (*British Patent* 127008. January, 1917.)

Details are given of a modulation arrangement for controlling the output from oscillation valves. The particular feature is the provision of a shunt between the grid and the filament, which is controlled by the transmitting microphone. In order to secure a sufficiently high impedance in this shunt, an inductance is placed in series with the microphone, and a tuning condenser across both microphone and inductance. The combined shunt is tuned to the oscillation frequency.

15. Wireless Telephone Transmitter for Seaplanes. (*Telegraph and Telephone Age*, pp. 342—346, July 16th, 1919.)

A description, with circuit diagrams, of the wireless telephone installations developed for use in seaplanes by the American Marconi Company. The transmitter comprises two valves, one for oscillation generator, and one for speech modulator, capable of working on 1,600 or 600 metres wave length.

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Speech transmission range = 150 miles. Telegraph signalling can be effected by means of a buzzer in the grid circuit of the modulator valve.

16. VACUUM TUBES. By M. Peri and J. Biguet. (*British Patent* 126658. October, 1915.) *

This patent, only just issued, although applied for in 1915, deals with the constructional details of three-electrode valves of the "French" type.

17. A NEW ELECTRON TUBE. By P. Donle. (*Radio Amateur News*, 1, p. 14, July, 1919.)

The valve described in this communication has the anode on the outside of the glass, with the usual spiral grid surrounding the filament in a vacuum. Best results were obtained with a silver anode. Curves of conductivity of the glass at various temperatures are given, and a characteristic curve of the complete valve.

18. RECEPTION THROUGH STATIC AND INTERFERENCE. By R. A. Weagant. (*Proceedings Inst. Radio Engineers*, 7, p. 207, June, 1919. *Electrician*, 83, pp. 84, 110, 180, August, 1919, Abstract.)

One of the greatest troubles in the operation of wireless receivers of all

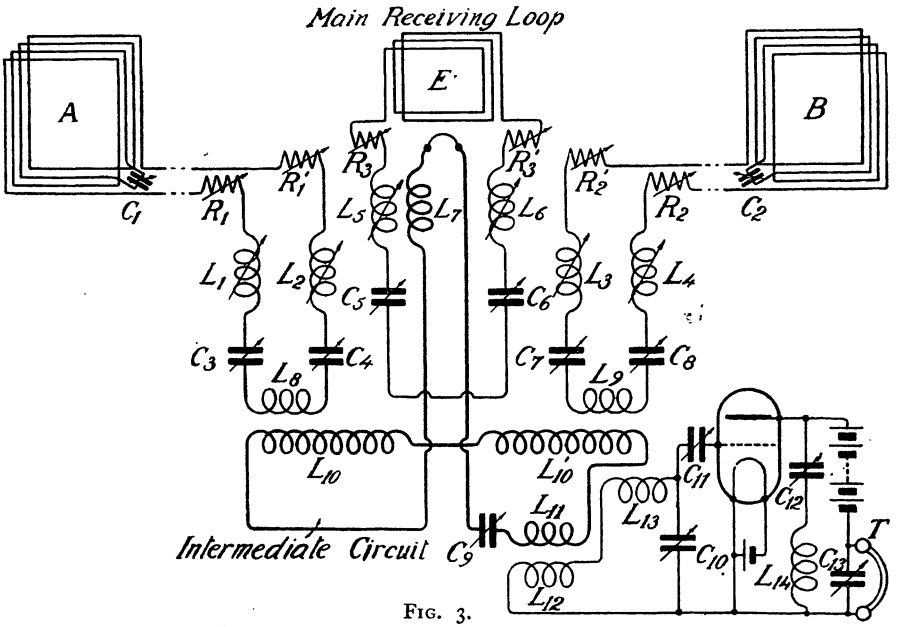

FIG. 3.

* The publication of a large number of radio patents has suffered considerable delay under war-time conditions. Some of these are now being issued, and they will be dealt with as available.

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types is the disturbance arising from the reception of atmospherics, strays, or X's. In this paper the author discusses the effects produced by the various classes of X's (grinders, clicks and hisses), and a series of researches is described bearing on the directive effect obtained with the various classes of X's. Clicks originating in fairly definitely positioned thunderstorms show a decided direction of propagation, but the grinder type of X appeared to have no definite direction determinable by ordinary direction-finding apparatus. The theory is put forward that the direction of propagation of atmospheric impulses of the grinder class is not horizontal, but vertical—

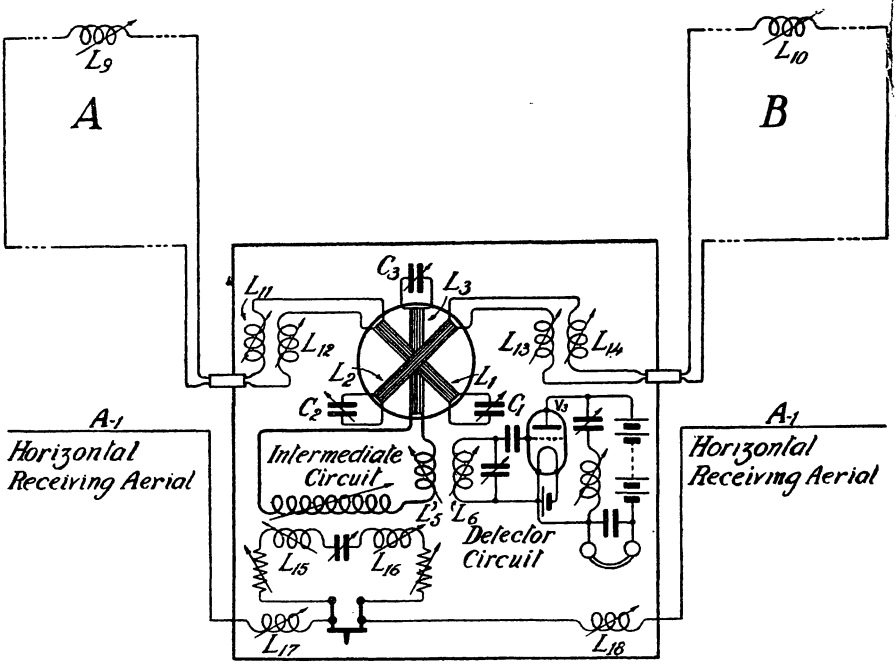

FIG. 4.

perpendicular to the earth's surface at the station—and that they behave as heterogeneously polarised waves, originating either overhead or underfoot.

Various experimental evidence collected during the research work is claimed to support this theory. One method adopted to take advantage of the above theory is indicated in Fig. 3. Two vertical loop aerials, *A* and *B*, are employed, spaced apart, with their plane in the line joining the receiving and transmitting stations, and connected up to a common radiogoniometer at the receiving station, which is placed midway between the two loops. Each loop circuit is provided with independent tuning inductances, L_1, L_2 and L_3, L_4. Coils L_8, L_9 form the fixed coils of the goniometer, while the moving coil, L_{10}, is coupled to the detector circuit through L_{11}, L_{12}. In order to secure the best results the centres of the loops *A* and *B* should be spaced

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one-half wave length apart, although smaller distances may also be used. Assuming this spacing, the currents set up in the two loop circuits are evidently of opposite phase, so that, by properly combining them through the goniometer, the impulses from the two loops become additive. Evidently, when this is the case, the currents induced in the two loops by the X's are in opposition, and so cancel out, since there is no appreciable phase difference between them. The resistances R_1, R_2, R_1', R_2' serve to equalise the decrements of the two circuits, to ensure a proper cancelling out of the X's.

Atmospherics of the "grinder" type are eliminated by this method.

To eliminate clicks as well as grinders, a similar principle is adopted, but in this case the spaced double loops are used to form a source of atmospherics of adjustable frequency and damping that may be used to oppose and cancel out the atmospherics received with the signal on the main receiving loop aerial (E in Fig. 3). Another scheme for this arrangement is indicated in Fig. 4, which shows a low horizontal aerial used for the main reception instead of a third loop. A and B are the two loops, which are connected so as to collect the atmospherics, but no signal, although tuned to the same frequency. Long low loops are preferred for these, running out as loops directly from the station to the extreme end, instead of being square loops connected by long lead-in wires, as indicated in Fig. 3. Inductances L_9, L_{10} are inserted in the centres of the top wires of the loops to facilitate tuning at the station. L_1, L_2, L_3, is the goniometer, having the moving coil L_3 joined into an intermediate circuit coupled, both to the detecting valve and to the main receiving aerials A_1, A_1, as indicated. With these arrangements trans-Atlantic radio reception has been carried on through heavy atmospheric disturbances without any interference from such causes.

2. Reviews of Books.

THE PRINCIPLES OF RADIOTELEGRAPHY. By Cyril M. Jansky, B.S., B.A. (New York: *McGraw Hill Book Co., Inc.* London: *Hill Publishing Co., Ltd.* Pp. ix. + 242. Price, 10*s.* net.)

This volume has been prepared in the Extension Division of the University of Wisconsin, and is intended as a students' text-book, rather than as an advanced treatise on radiotelegraphy, and, for this purpose, it is undoubtedly a useful contribution to the literature of that subject, although there is little really new matter contained in its pages.

Since radiotelegraphy is an electromagnetic phenomenon, and electric and magnetic apparatus is employed in the generation and detection of the waves, practically half the book is devoted to a discussion of electric and magnetic principles. This introduction is most desirable for a proper understanding of radio working by students fresh to the subject. In Chapters VII. and VIII. the author deals in a general way with oscillatory circuits, and in a more detailed manner with radio circuits, while the last three chapters are devoted to radiotelegraphy proper, and discuss the various arrangements of transmitters and receivers, with illustrations of different types of American apparatus.

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The American custom of inventing fresh terms and expressions in describing apparatus slightly mars the value of the book for English students. For instance, such terms as *susceptance* (on p. 137) do not really explain anything, and are only extra terms to be memorised. "Capacitance," used for ordinary capacity, is perhaps more logical, as it brings the expression in line with inductance, resistance, etc., although the value of its use is open to difference of opinion.

In a few parts of the book rather incorrect ideas might be gathered. Perhaps the worst instance is in Fig. 147, described as "Typical Connections of a Receiving Station." This shows a coupled crystal receiver with the mistake, often made by W/T. operators, of feeding their crystal testing buzzer from the potentiometer cells of their receiver. Such an arrangement gives a sound in the telephones whatever the condition of the crystal. Further, the buzzer is also shown as coupled to the telephone circuit instead of to the crystal oscillatory circuit, or preferably to the aerial. This would also give false indications as to the condition of the crystal for reception. The whole trouble can, of course, be removed by coupling the test buzzer to the aerial circuit, and feeding it from an independent battery.

In the description of valve circuits the author misspells Dr. Fleming's name; and, in describing the heterodyne receiver, only shows an arc as the local source of oscillations—surely an arrangement fast becoming obsolete. It is not obvious why Fig. 179 should be described as a combined radio-telegraph and *telephone* circuit, when apparently there are no means provided for transmitting speech. The circuit shown is more correctly a species of "Tonic Train" transmitter.

Speaking of wireless telephones (which are scarcely mentioned), the use of the term "radiotelephone" (though common in America for this purpose) scarcely seems justified for describing simply a headgear telephone receiver. The term ought to be strictly confined to the complete wireless telephone apparatus, as in the analogous case of "radiotelegraph."

The description of the Goldschmidt alternator is not very clear, although the correct ideas are given. On p. 167 the author says, "In this manner the damping is *reduced*, which is called *quenching*" (the italics are mine). Quenched spark gaps usually give very high damping in their circuits, and it is not made clear that it is the decrement of the *aerial* oscillations that is reduced when such gaps are used.

Actual misprints are very few, but the transposition of the figures on pp. 4 and 5 might cause confusion to a new student. Inaccuracies on pp. 93, 169, 176, and in the numerical index in the wave-length formula on p. 180 should also be mentioned.

The treatment of the subject is quite good on the whole, and no difficult mathematics is used, while the numerical examples at the ends of the chapters and throughout the text should be very helpful. They might, however, be somewhat more useful if given in the more usually adopted practical units, particularly for the wave-length formulæ.

The general appearance of the book is good, and the printing clear. It should prove on the whole a useful radio text-book for students' use.

P. R. C.

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THE
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Ionic Oscillations in Three-Electrode Thermionic Valves.*

By R. WHIDDINGTON, M.A., D.Sc. (Cavendish Professor of Physics, University of Leeds).

IT is well known that if capacity inductance circuits of low resistance be associated with a valve in the manner shown in Fig. 1 oscillations may be set up in the anode circuit having a period very nearly equal to $2\pi\sqrt{LC}$ providing that:

(1) The resistance R of the anode circuit is small.

(2) The "resistance" ρ of the valve is great.

(3) The mutual induction M between the grid and anode coils is only just great enough to maintain oscillations, a condition approximately realised when $M > 1/k\,(L/\rho + R\,.\,C)$ where k is the so-called factor of amplification.

This method of producing oscillations has been very largely used for many purposes, particularly in wireless

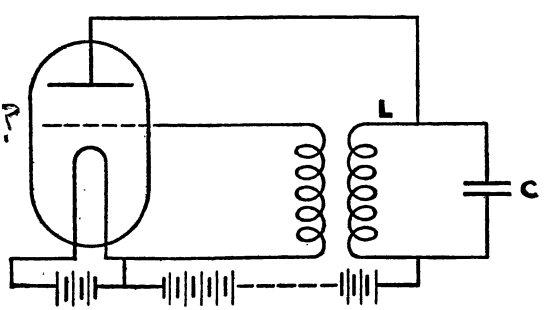

FIG. 1.

* This article contains the text of a paper, entitled "A Wireless Method of Measuring the Ratio e/m," read before Section A of the British Association, together with subsequent additions made by the author.

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telegraphy and telephony, and in modern practice is usually employed in conjunction with "hard" valves, that is to say valves from which gas and vapour have been removed to such a degree as to prevent the production of ions by collision.

The arrangement of Fig. 1 can however be used equally successfully and usually more efficiently with "soft" valves which contain sufficient quantities of gas or vapour as to permit of ionisation by collision.

It is the object of the present short paper to show that by employing a new and simple scheme of circuits a soft valve can be made to oscillate in a way involving very different principles to those obtaining in the arrangement of Fig. 1. The new arrangement is shown diagrammatically in Fig. 2.

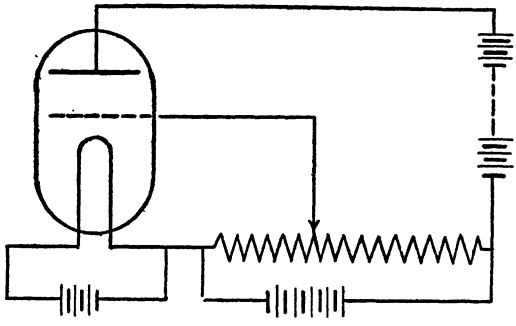

FIG. 2.

It is seen here that there are no capacity inductance circuits whatever, in effect simply two sources of potential, the one in the anode circuit being of fixed value, that in the grid circuit being variable. Experiment has shown that in an arrangement of this sort quite strong oscillations may be set up with a frequency which is determined almost entirely by the value of the grid potential and geometrical dimensions of the valve electrodes. In Fig. 2 the variable grid potential is represented by a potentiometer, which in practice was non-inductive and consisted in fact of a soft lead pencil split lengthways and fitted with a small metal sliding contact.

The oscillations were detected and their frequency measured by means of a heterodyne wave-meter placed in the vicinity, there being always sufficient energy radiated from the self-oscillating valve to be appreciable up to a few yards away.

It will be convenient at this stage to outline a simple theory which accounts, broadly speaking, for the observed phenomena.

An assumption that has to be made at the outset is, that although the filament as a whole is emitting electrons continuously according to the accepted exponential temperature law, yet there are often one or more spots which are emitting with exceptional power.

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Such spots in the case of a tungsten filament are probably of chemical origin and may be due to the presence of local impurity. They would certainly be very sensitive to small temperature changes. It is further necessary to suppose that the bombardment by positive ions of the filament in the neighbourhood of such an emitting spot would greatly increase the local electronic emission so long as the bombardment lasted.

Very direct evidence of the existence of such selectively emitting spots on a tungsten filament is afforded in the experience of manufacturers of valves. It is customary in the factories to "clean up" the anode by passing a comparatively heavy thermionic discharge through the valve when on the pump. During this process the dissipation of energy at the anode is so regulated that the metal of the anode is maintained at a red heat, when it is often observed that one or more points on the anode are very much hotter than the main surface. This fact can only be explained on the assumption that there is exceptionally powerful emission from the corresponding points on the filament.

Now consider one such spot on the filament. If a burst of electrons be emitted they will proceed towards the grid with a speed u given by $\frac{1}{2} m u^2 = e.V$ so that $u^2 = 2V.e/m$ where e/m is the charge to mass ratio for the electron and V is the value of the positive grid potential with respect to the particular point on the filament considered.* The electrons will thus take a definite and calculable time to travel from filament to grid under the moderate potential applied. On passing through the grid however the electrons emerge into the strong electric field of the anode and assume ionising speed. The negative ions follow the electrons to the anode but the positive ions pass back through the grid towards the filament with speed

$$u_1^2 = 2\,V.e/m_1$$

where e/m_1 is in this case the charge to mass ratio of the ion concerned.

There will thus be a cloud of positive ions focussed on the filament and bombarding the original electron emitting spot. This bombardment by producing a new burst of electrons sets up a self-sustaining current oscillation, whose period is determined

* It is assumed as an approximation that the filament is screened from the anode by the grid. This is very nearly true for the fine-meshed grid of the valve used in the present experiments.

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(for any particular valve) solely by the charge to mass ratio of the ions present and the potential applied to the grid.

The following table shows what frequency and wave-length of oscillations would be expected from the above general explanation for the particular case of a valve of the type actually used in the experiments, having a fine-meshed cylindrical grid 6 mm. in diameter down the axis of which passed the filament.

The frequencies corresponding to the singly charged ions of hydrogen and mercury moving under the influence of 1 volt applied to the grid are there evaluated.

Charged Particle.	e/m (approx.)	u (cms./sec.)	n (cycles/sec.)	Wave-length (metres).
Electron .	$1{\cdot}7 \times 10^7$	$6{\cdot}0 \times 10^7$	$4{\cdot}0 \times 10^8$	0·77
Hydrogen .	10^4	$1{\cdot}4 \times 10^6$	$1{\cdot}0 \times 10^7$	30
Mercury .	50	$1{\cdot}0 \times 10^5$	$6{\cdot}6 \times 10^5$	450

In actual experiments it was found that the arrangement of Fig. 2 with an applied grid potential of 1 volt, radiated energy at a frequency between $7{\cdot}0 \times 10^5$ and $4{\cdot}0 \times 10^5$ cycles. On the preceding explanation therefore such oscillations are to be ascribed to mercury vapour. It is to be noted however that the frequencies tabulated above are calculated on the basis of singly charged monatomic ions. If in the case of mercury vapour polyatomic ions are concerned a different frequency will be associated with each ion, the frequencies for singly charged ions consisting of two, three, and four atoms respectively would be $1/\sqrt{2}$, $1/\sqrt{3}$, $1/\sqrt{4}$ times $6{\cdot}6 \times 10^5$ (the frequency corresponding to the monatomic ion).

These expected frequencies are tabulated below, while in the second column are given the frequencies actually obtained experimentally. It will be seen that there is a remarkable agreement between the expected and observed frequencies.

Number of Atoms in Molecule.	Theoretical Frequency (1 Grid Volt).	Observed Frequency (1 Grid Volt).
1	$6{\cdot}6 \times 10^5$	$6{\cdot}4 \times 10^5$
2	$4{\cdot}7 \times 10^5$	$4{\cdot}6 \times 10^5$
3	$3{\cdot}8 \times 10^5$	$3{\cdot}5 \times 10^5$
4	$3{\cdot}3 \times 10^5$	—

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Oscillations in addition to the above have been detected and measured, they are believed to be due to the carbon dioxide ion but have not yet been investigated in detail.

Referring back to the formula it will be seen that the square of the speed of the ions, that is, the square of the oscillation frequency, should be proportional to the potential applied to the grid. This prediction is amply borne out in practice; curves plotted between n^2 and V yielding in all cases so far investigated excellent straight lines. These lines cut the axis of V at points determined partly by the position of the emitting spot on the filament and partly by the natural emission velocity of the electrons.

A typical curve * found by plotting n^2 against V is shown in Fig. 3, an obvious straight line giving a value of $n = 6{\cdot}4 \times 10^5$ for a grid potential of 1 volt. That the line produced passes through the origin is probably only accidental.

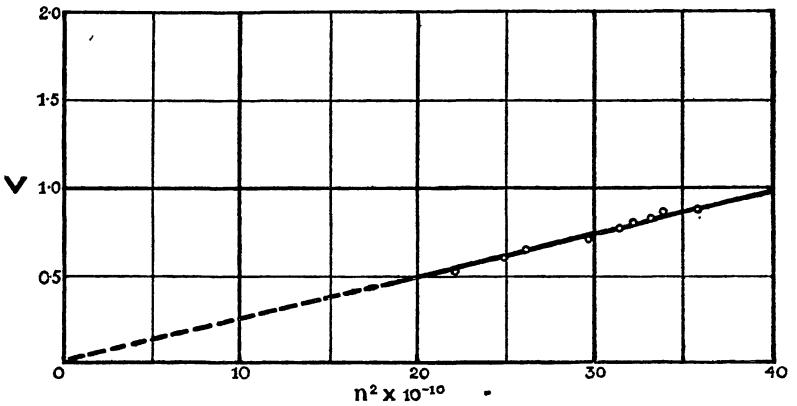

FIG. 3.

It can be seen at once that, if the electrons have a negligible speed of emission, the value of $V = V_0$ for which $n^2 = 0$ must determine the position of the emitting spot on the filament.

In fact if v = the potential fall along the hot filament

L = the length of the filament

and if the potentiometer of Fig. 2 is connected to the negative end of the filament, then

$V_0/v.L$ = the distance of the spot from the negative end of the filament.

* The value of e/m of the ion responsible for the oscillation determines the slope of the curve.

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It is clear also that these straight lines should always cut the V-axis at positive values of V. In practice this has not always been found to be the case, a fact which it is believed may be more apparent than real and due to the confusion of harmonics with the fundamental oscillation.

This short paper does not in any way aim at completeness; it is intended merely to introduce what is believed to be a new and at first sight rather an astonishing oscillating valve circuit.

The method opens up new fields for research, such for example as the development of a method of determining e/m, and the production of extremely short wireless waves, which it is hoped will be dealt with in future papers.

Some of the work above described was carried out at the Air Force Wireless Experimental Establishment, Biggin Hill, where I was assisted in these experiments by Miss B. Summerhayes, B.Sc., and Lieutenant H. Richardson, R.A.F., B.Sc.

On the Goniometric Functions Applicable to Directive Aerials.

By A. BLONDEL.

(*Continued from page* 10.)

THE APPLICATION OF THE "ZERO METHOD," OR THE SINGLE FRAME METHOD, TO DIRECTION FINDING.

IF it is desired to employ a single-frame arrangement to determine the direction of incoming waves, the frame should be turned until the sound in the telephones just disappears; the angle ψ_1 between a horizontal line perpendicular to the plane of the frame and the north as given by the compass is noted. The frame is then turned in the opposite direction until a second position is found where the sound disappears. Let ψ_2 be the new angle between the line perpendicular to the frame and the north. The two directions obtained in this manner are not coincident, owing to lack of sensitiveness of the telephone and ear, but they correspond, one to a small positive value of the resultant electromotive force, and the other to a small negative value obtained by reversing the signs of E_1 and E_2. The corresponding phase

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angles ϕ_1 and ϕ_2, in the case of the type D arrangements, are given by the following equations :—

$$\left.\begin{aligned} a[2e_0 \sin\phi_1]^2 &= \epsilon' \\ a[2e_0 \sin(-\phi_2)]^2 &= \epsilon' \end{aligned}\right\} \quad . \quad . \quad . \quad (5)$$

assuming that the detector gives a response proportional to the square of the resultant E.M.F., a being a co-efficient of proportionality.

Hence, $$\phi_1 = \sin^{-1}\left(\sqrt{\frac{\epsilon'}{a}} \times \frac{1}{2e_0}\right) \quad . \quad . \quad . \quad (6)$$

In a more general case, using the function F to represent the response of the detector, the above equations become

$$F[2e_0 \sin\phi_1] = \epsilon'. \quad . \quad . \quad . \quad (7)$$

$$F[2e_0 \sin(-\phi_2)] = \epsilon'. \quad . \quad . \quad . \quad (8)$$

In all cases we have $\phi_1 = \phi_2$, that is to say, the required direction is the bisector of the angle $\psi_1 - \psi_2$. But the size of this angle and the accuracy of measurement vary with ϕ_1. In fact, writing H for the inverse function of F, the following equations may be deduced

$$\psi_1 - \psi_2 = \phi_1 - \phi_2 = 2 \sin^{-1} H\left(\frac{\epsilon'}{2e_0}\right). \quad . \quad (9)$$

where $$\phi_1 = \sin^{-1} H\left(\frac{\epsilon'}{2e_0}\right).$$

Also, since $\theta = \sin^{-1}\frac{\lambda\phi_1}{2\pi x}$, the error in the angle θ has the following value, corresponding to an error $d\epsilon'$ in determining the audibility limit,

$$d\theta = \frac{d\phi_1}{\sqrt{\left(\frac{2\pi x}{\lambda}\right)^2 - \phi_1^2}} = \frac{\frac{d}{d\epsilon'} H\left(\frac{\epsilon'}{2e_0}\right) d\epsilon'}{\sqrt{\left(\frac{2\pi x}{\lambda}\right)^2 - \phi^2}\sqrt{1 - \left[H\left(\frac{\epsilon'}{2e_0}\right)\right]^2}} \quad . \quad . \quad . \quad (10)$$

In the case of an energy integrating detector, this expression reduces to

$$d\theta = \frac{d\epsilon'}{\sqrt{\left[\left(\frac{2\pi x}{\lambda}\right)^2 - \phi^2\right]\left[(2e_0)^2 - \epsilon'^2\right]}} \quad . \quad . \quad (10a)$$

It will be seen that the possible error $d\theta$ depends, not only on

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the angle θ itself (which enters into the expression for ϕ_1) and on the minimum response ϵ', but also on the E.M.F., $2e_0$, induced by the waves, and, consequently, on the distance of the frame aerial from the transmitter and on the power of the latter. The definiteness of the measurement is obviously greater when the received waves are weaker.

Similar formulæ can be obtained for the S type loops by replacing $\sin\phi$ by $\cos\phi$; but, like the preceding expressions, they only permit numerical calculations to be made if the formulæ (5) and (6) are applicable.

From the preceding remarks it follows that the efficacy of the simple type D frame can be augmented by increasing the power of the transmitting station and the sensitiveness of the receiving detectors, so that angles greater than 30° to 40° are not obtained on either side of the mean position. Measurements made with larger angles must be looked upon as less reliable.

The single-frame arrangement has the advantages of simplicity and of ease of application in all practical cases. There is little risk, in general, of its giving false directions through bad insulation. In such cases it may cease to be usable, either through giving rise to no measurable effect on the detector, or for yielding a constant E.M.F. in every position. In either case the operator is warned that there is something wrong. A single aerial of the S type presents equally serious defects. On the one hand, as has been seen above, it only gives good results when $\frac{x}{\lambda}$ is very near $\frac{\lambda}{4}$, in fact, for small values of $\frac{x}{\lambda}$ the effect of the waves on the frame becomes almost independent of the orientation of the loop. Further, the sensitiveness, which is zero when $\theta = 0$, also becomes zero when $\theta = 90°$. The limits of utility are, therefore, far more restricted than in the case of the type D arrangement. Type S is, therefore, only of theoretical interest, and is not likely to be used in practice.

Application of the Comparison Method.

Suppose for simplicity that the current induced in the local circuit is proportional to the resultant induced electromotive force and that the detector by complete rectification gives a response proportional to the amplitude of this current, then the

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equations can easily be written for all direction-finding arrangements by the comparison method with several loops.

For example, taking the case of two identical loops perpendicular to one another and coupled differentially by transformers, having variable transformation ratios M and N, to a single circuit containing the detector, the comparison method becomes a *compensation method* by opposing the effect of the two loops, so as to reduce the indication of the measuring instrument to zero. Hence the relation

$$M \operatorname{gon} \theta - N \operatorname{gon} \left(\frac{\pi}{2} - \theta\right) = 0.$$

But, in practice, using a telephone instead of a galvanometer, the measurement is made by determining two values of the coefficients of mutual induction M and N when the sound disappears in the telephone. Hence assuming firstly the response of the detector proportional to the square of the acting electromotive force, we have

$$\left.\begin{aligned} M \operatorname{gon} \theta - N \operatorname{gon} \left(\frac{\pi}{2} - \theta\right) &= \sqrt{\frac{\epsilon'}{2ae_o}} \\ M' \operatorname{gon} \theta - N' \operatorname{gon} \left(\frac{\pi}{2} - \theta\right) &= -\sqrt{\frac{\epsilon'}{2ae_o}} \end{aligned}\right\} \quad \ldots \quad (11)$$

where a is a coefficient of proportionality and ϵ' a very small quantity corresponding to the threshold value of the sound in the telephones.

These quantities may be eliminated by adding the two equations whence,

$$\frac{\operatorname{gon} \theta}{\operatorname{gon}\left(\frac{\pi}{2} - \theta\right)} = \frac{N + N'}{M + M'} \quad \ldots \ldots \quad (12)$$

In the case of the well-known apparatus, called by its inventors the "radiogoniometer," the two transformers are replaced by a single apparatus comprising two fixed primary circuits at right angles, and a secondary circuit which can be rotated about their common axis.

If we call ψ the angle between the electrical axis of the movable coil and that of one of the fixed circuits, we have

$$M = \cos \psi ; \; N = \sin \psi$$
$$M' = \cos \psi' ; \; N' = \sin \psi'$$

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from which we obtain,

$$\frac{\text{gon}\,\theta}{\text{gon}\left(\frac{\pi}{2}-\theta\right)}=\frac{\sin\psi+\sin\psi'}{\cos\psi+\cos\psi'}=\tan\frac{\psi+\psi'}{2} \quad . \quad (13)$$

In the particular instance when the frame width x is very small in comparison with the wave length, the functions $\frac{2\pi x}{\lambda}\sin\theta$ and $\frac{2\pi x}{\lambda}\cos\theta$ are practically equal to the angles, so that the last term of the above equation reduces simply to $\tan\theta$, wherefore substituting β for $\frac{\psi+\psi'}{2}$, we have $\theta=\frac{\psi+\psi'}{2}=\beta$.

Firstly let us take the case of Type D arrangement:

If we plot, as in Fig. 9, the values of θ from 0° to 90° as abscissæ, and the values of β as ordinates, where

$$\beta=\tan^{-1}\left(\frac{\frac{2\pi x}{\lambda}\sin\theta}{\frac{2\pi x}{\lambda}\cos\theta}\right)=\theta,\ \textit{nearly} \quad . \quad . \quad . \quad . \quad (14)$$

we obtain a straight line.

But this is only the case for long wave lengths. When shorter wave lengths of the order of 100 metres are used, β is replaced by a more complicated function :—

$$\beta_D=\tan^{-1}\frac{\text{gon}\,\theta}{\text{gon}\left(\frac{\pi}{2}-\theta\right)}=\tan^{-1}\frac{\sin\left(\frac{2\pi x}{\lambda}\sin\theta\right)}{\sin\left(\frac{2\pi x}{\lambda}\cos\theta\right)} \quad . \quad . \quad (15)$$

Fig. 9 gives the values of β_D as a function of θ and conversely, for $\frac{x}{\lambda}=\frac{1}{4},\frac{1}{8},\frac{1}{16}$. The difference between β and β_D is negligible when $x=\frac{\lambda}{16}$, it reaches a maximum of 7° 30′ when $x=\frac{\lambda}{4}$ approximately, and becomes zero in every case, whatever the value of x, when $\beta=0°$, 45° and 90°.

To employ a radiogoniometer accurately, it is necessary to plot a correction curve similar to the preceding, giving θ in terms of β, and *vice versâ*, for each value of $\frac{x}{\lambda}$ that is used, or else to employ a double-entry table.

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If we use type S arrangement instead of type D, the angle β is given by an analogous expression, the sines being replaced by the cosines

$$\beta_S = \tan^{-1} \frac{\cos\left(\frac{2\pi x}{\lambda}\sin\theta\right)}{\cos\left(\frac{2\pi x}{\lambda}\cos\theta\right)} \quad \ldots\ldots\ldots \quad (16)$$

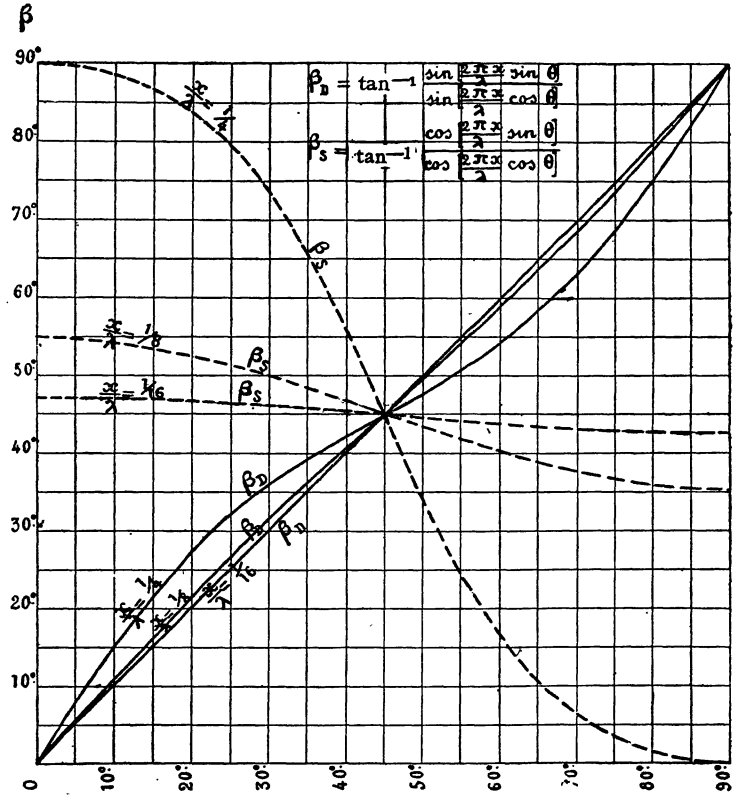

FIG. 9.

By plotting the curves of β_S for different values of $\frac{x}{\lambda}$, Fig. 9, we see that they are of a different type from those of β_D. When $\frac{x}{\lambda} = \frac{1}{4}$ the curve for β_S is the inverse of that for β_D—*i.e.* θ is replaced

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by $\left(\frac{\pi}{2} - \theta\right)$. But as $\frac{x}{\lambda}$ decreases, the value of β_s tends to become constant, instead of being proportional to θ. The sensitiveness therefore falls off as the width of the loop becomes less than a half wave length.

For that reason there is no further interest in considering the type S arrangements for direction finding; the same argument applies even more, if frame arrangements with slanting aerials are used.

Instead of operating by *compensation* as above, we may utilise *alternate* measurements, as I indicated in 1910,* by arranging the two loops to influence the same receiving circuit or telephones in turn, and altering the mutual inductances M and N until the two sounds become equal—thus making use of the *differential* sensitiveness of the ear instead of its ultimate threshold sensitivity. The preceding equations remain valid (with another ϵ' of course), if the detector gives a response proportional to the amplitude or the square of the amplitude, of the electromotive force in the loop, or even if it follows some other function of the voltage.

In the last case, theoretically the most complex, each of the expressions $\text{gon}\,\theta$ would be replaced by the unknown and more complex function $F(e_o \,\text{gon}\,\theta)$. This, however, does not hinder the solution of the equations for the compensation method, since, by writing H for the inverse of the function F, the two expressions (11) can immediately be replaced by the following:

$$\left.\begin{aligned} M\,\text{gon}\,\theta - N\,\text{gon}\left(\frac{\pi}{2} - \theta\right) &= H\left(\frac{\epsilon'}{2e_o}\right) \\ M'\,\text{gon}\,\theta - N'\,\text{gon}\left(\frac{\pi}{2} - \theta\right) &= -H\left(\frac{\epsilon'}{2e_o}\right) \end{aligned}\right\} \quad . \quad . \quad (17)$$

Adding these two expressions, the unknown function on the right hand side is eliminated, and the following equation obtained,

$$\frac{\text{gon}\,\theta}{\text{gon}\left(\frac{\pi}{2} - \theta\right)} = \frac{N + N'}{M + M'} = \tan\beta, \text{ say} \quad . \quad . \quad . \quad (18)$$

All the results previously found therefore remain without alteration. In the particular case, for the radiogoniometer,

$$\tan\beta = \tan\frac{\psi + \psi'}{2}.$$

* A. Blondel, *loc. cit.*

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In the case of the alternate measurement method the function H cannot be introduced, so that equation (11) must be replaced by the following:

$$\left.\begin{aligned} F\,(2e_0 M \operatorname{gon}\theta) - F\left[2e_0 N\left(\frac{\pi}{2}-\theta\right)\right] &= \epsilon' \\ F\,(2e_0 M' \operatorname{gon}\theta) - F\left[2e_0 N' \operatorname{gon}\left(\frac{\pi}{2}-\theta\right)\right] &= -\epsilon' \end{aligned}\right\} \quad . \quad (19)$$

When the detector is not a crystal but an energy integrating one F indicates a square, and we obtain:

$$\frac{\operatorname{gon}\theta}{\operatorname{gon}\left(\frac{\pi}{2}-\theta\right)} = \sqrt{\frac{N^2+N'^2}{M^2+M'^2}}$$

which is comparatively simple. But if F is any unknown quantity, the solution of (19) cannot be obtained immediately but a previous knowledge is required of the function F and of the variation of e_0 with the distance from the transmitter.

The comparison method then, is preferable to the alternate measurement method. Moreover it should be noted that it gives a more uniform degree of accuracy when θ varies. Indeed, assuming that the measurement of θ is accomplished directly by a galvanometer, as may be done with the radiogoniometer, we have, as above,

$$M \operatorname{gon}\theta - N \operatorname{gon}\left(\frac{\pi}{2}-\theta\right) = 0 \quad . \quad . \quad . \quad . \quad (20)$$

Any variation $d\theta$ of the angle θ then makes this expression equal to a small quantity $d\alpha$ instead of zero. The relative accuracy is then:—

$$\frac{d\alpha}{d\theta} = M\frac{d\operatorname{gon}\theta}{d\theta} - N\frac{d\operatorname{gon}\left(\frac{\pi}{2}-\theta\right)}{d\theta} \quad . \quad . \quad . \quad (21)$$

When M and N are equal respectively to $\cos\psi$ and $\sin\psi$, as above, and when the distance between the antennæ is sufficiently small to allow the use of the simplest form of the goniometric function $\left[\operatorname{gon}\theta = \frac{2\pi x}{\lambda}\sin\theta;\ \operatorname{gon}\left(\frac{\pi}{2}-\theta\right) = \frac{2\pi x}{\lambda}\cos\theta\right]$, the second term of equation (21) reduces to

$$\frac{2\pi x}{\lambda}(\cos^2\theta + \sin^2\theta) = \frac{2\pi x}{\lambda} \quad . \quad . \quad . \quad . \quad . \quad (22)$$

and is therefore a constant.

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If the detector integrates the energy proportional to the square of the first term of (20), the accuracy of measurement is given by

$$2\frac{da}{d\theta}\left[M \operatorname{gon}\theta - N \operatorname{gon}\left(\frac{\pi}{2}-\theta\right)\right] = 8\left(\frac{\pi x}{\lambda}\right)^2 \operatorname{gon}(\theta-\psi). \quad (21a)$$

If M and N can be varied independently the relative accuracy remains proportional to the expression (21), but increases with the absolute values of M and N, which are assumed always to satisfy equation (19). This shows that it is always advisable to increase as much as possible the mutual inductance of the transformer supplied by the loop receiving the weakest electromotive force.

On the contrary in the comparison system using alternate measurements, gon θ must be replaced by F (gon θ), a function dependent upon the mode of operation of the detector; and the sensitiveness is no longer constant. However, if the detector is a simple energy integrator, $F(\operatorname{gon}\theta) = (\operatorname{gon}\theta)^2$ and (20) becomes

$$M^2 \operatorname{gon}^2\theta - N^2 \operatorname{gon}^2\left(\frac{\pi}{2}-\theta\right) = 0 \quad . \quad . \quad . \quad (20a)$$

NON-VERTICAL AERIALS.

We have assumed up to the present that the antennæ or sides of the loops are vertical, with the exception of the horizontal parts which serve merely for connections.

In cases where the shape of the loop is more complicated, the function gon θ will be replaced by a more complicated expression.

The only condition desirable for each such system of connected aerials, if they are of complicated shape, is that they shall be symmetrical at least about a vertical line in their plane midway between them.* Let us therefore consider two symmetrical aerials, and that (x, z) are the co-ordinates of any point in one of them, z being the height measured from the horizontal plane passing through the lowest point of the aerial, or, more generally, from any horizontal reference plane. The co-ordinates of a point at the same height on the second aerial will be $(-x, z)$. The equation of each antenna in the plane of the loop can therefore be expressed in the form $x = f(z)$ $-x = -f(z)$.

(To be concluded.)

* This condition is not, however, absolutely essential, since it is always possible to integrate the electromotive force of the two antennæ separately, by referring their phase angle to a vertical reference axis. But this results in a rather troublesome complication especially when the damping is considered. (See below.)

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An Investigation of the Internal Action of a Triode Valve.

By W. H. ECCLES, D.Sc., M.I.E.E.

(*Continued from page* 20.)

Theory of the Grid.

Triode with Plane Electrodes.

We shall first suppose the cathode and anode to be parallel planes of infinite extent and the grid to consist of a number of equidistant straight parallel wires with their axes in a plane parallel to the electrodes. The cathode will be supposed to be emitting the electrons uniformly over its surface. We begin by endeavouring to picture the instantaneous state of the electric field between the electrodes. The form of the lines of force is suggested in Fig. 7. Since the triode is usually used with the anode at much higher potential than the grid and the cathode, the Faraday lines are portrayed as starting on the anode A and ending on the grid G and on the electrons of the space charge. Near the anode the density of the lines is uniform and the lines are perpendicular to the anode. They remain nearly parallel till near the grid wires, and here the radial field due to the charge on the

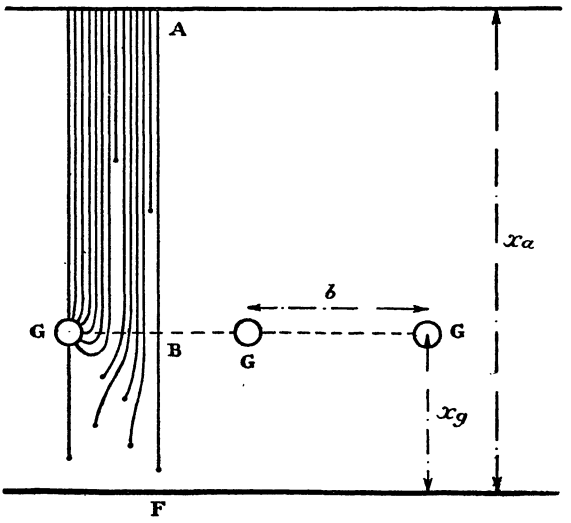

Fig. 7.

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grid combines with the parallel field to give the curved lines. Passing into the region between the grid G and the cathode F the field tends to become uniform again, but is clearly much weaker on account of many of the lines having been disposed of. None of the lines reach the cathode, because the field, as we have already seen, must be zero at or near the cathode; that is to say, all the lines that penetrate the shield formed by the grid end upon flying electrons. In the figure there is marked a region B wherein the grid exerts very little influence. We shall make this a kind of resting place in our calculation of the voltages between different points in the field.

Let x_a represent the distance of the anode from the cathode, x_g the distance of the plane of the grid from the cathode, b the distance between consecutive grid wires, r the radius of each grid wire, and v_a, v_b, v_g the potentials of the points A, B, G relative to the cathode F. Among the lengths r will be supposed small compared with b, and b small compared with x_a and x_g. We shall now estimate the voltages between the points A and B, B and G, B and F, and shall make these obey the condition that all the Faraday lines leaving A end upon the grid and upon electrons. In order to do this without great labour it is necessary to make some simplifying approximations at the very beginning. First we shall assume that the electric field is practically constant all the way from A to B; then, if σ_a be the number of lines starting from the square centimetre of anode, the field is $(4\pi/\kappa)\sigma_a$, where κ is the inductivity (S.I.C.) of the vacuum, and the P.D. between A and B is

$$v_a - v_b = 4\pi\sigma_a (x_a - x_g)/\kappa.$$

Next let the charge on every centimetre of each wire of the grid be Q, then, since there are $1/b$ wires per centimetre, the amount of electricity per square centimetre on the grid is Q/b. Now, in estimating the P.D. between B and G, we may suppose a unit test charge of electricity moved from B to G under the electric forces due to the whole of the grid wires, and calculate the work done. The contribution of each grid wire to the voltage is of the form

$$\frac{2Q}{\kappa} \log \left(\frac{\text{initial distance}}{\text{final distance}}\right),$$

where the distance is to be measured from the centre of the wire concerned. The sum of all such logarithms is of the form

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$$\frac{2Q}{\kappa} \log \frac{\beta}{r}$$

where β is a geometrical constant that can be determined by calculation for any number of wires, if required. For one wire β is clearly $\frac{1}{2}b$, for two wires, one on each side of B, $\beta = \frac{1}{4}b$, and so on. We obtain, therefore,

$$v_b - v_g = \frac{2Q}{\kappa} \log \frac{\beta}{r}.$$

The next step is to evaluate the voltage between B and F. We do this by aid of the electron current equation given on p. 13, which states that when an electronic current of density i is flowing between two parallel plane areas at one of which the voltage and the electric field are zero, the P. D. is

$$v_b = (i/A)^{\frac{2}{3}} x_b^{\frac{4}{3}}.$$

The last of the equations to be formed is, as already explained,

$$\begin{aligned} \sigma_a &= Q/b + \text{all space charge} \\ &= \alpha Q b/, \text{ say,} \end{aligned}$$

where α is a quantity to be determined by experiment, and obviously approaches unity when the space charge, that is to say, the electron current, is very small. Experiment shows that for most types of triode α is nearly equal to unity for a large range of values of grid voltages and anode current, but the mode of derivation shows that it should tend to increase as the electron current increases.

We now have four equations amongst the seven variable quantities, and can, therefore, eliminate three of them, say α_a, Q and v_b. From the first equation we obtain σ_a, from the second, Q; substituting these in the fourth equation, we have

$$v_a - v_b = \frac{2\pi\alpha (x_a - x_g)}{2b \log \beta/r} (v_b - v_g)$$

or

$$v_a + g v_g = (1 + g) v_b,$$

where we have put, for brevity,

$$g = \frac{2\pi\alpha (x_a - x_g)}{b \log \beta/r},$$

and where the logarithm is natural.

Now using the third equation we obtain

$$v_a + g v_g = (1 + g) (i/A)^{\frac{2}{3}} x_g^{\frac{4}{3}},$$

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or $$i = A\frac{(v_a + gv_g)^{\frac{3}{2}}}{(1+g)^{\frac{3}{2}}x_g^2}.$$

This formula for the planar triode is not of immediate utility, because very few, if any, instruments have been made with the cathode consisting of a heated plane surface. Even in those cases where the anode and the grid are planes the cathode is usually a filament, which may in large lamps be wound to and fro between the grid so as to form a number of V's; and to this the formula is not genuinely applicable. The same method may, however, be applied to the cylindrical triode, and to this we now turn.

THE CYLINDRICAL TRIODE.

The cathode will be taken to be a straight filament or a curled filament with straight axis and of small over-all diameter, while the anode will be taken to be a circular cylinder co-axial with the cathode. All the electrodes are supposed to be of infinite length. The grid will be taken to be a co-axial intermediate helix with equidistant spires or a collection of equal parallel equidistant co-axial circles. In Fig. 8 a sectional view is given, and A is the anode, F the cathode, G the grid. When, as is usual, the anode is at higher potential than the other electrodes, the Faraday lines starting from the inside surface of the anode form a converging radial electric field in which every line of force ends upon the grid or upon an electron in the space charge conveying the current. Let the radius of the grid wire be r, the distance between consecutive turns b, the radius of the grid helix x_g, and the radius of the inner surface of the anode x_a. Also let the charge per unit length of the anode be Q_a, and that upon unit length of the wire of the grid Q. It follows that the charge per unit length of the grid helix is approximately

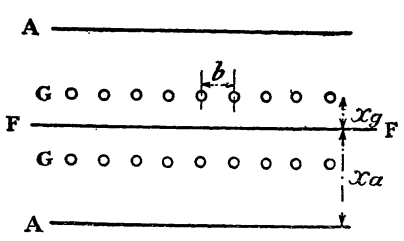

FIG. 8.

$$2\pi x_g Q/b$$

The analysis now follows closely that used in the case of the planar triode. But the potential between A and B is due on the present occasion to a radial field, and the P.D. is therefore a logarithm; that is to say,

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$$v_a - v_b = \frac{2Q_a}{\kappa} \log \frac{x_a}{x_g}.$$

The next equation is, by reasoning the same as before,

$$v_b - v_g = \frac{2Q}{\kappa} \log \frac{\beta}{r},$$

and then from the properties of the electron current flowing between cylinders we have

$$v_b = (j/2\pi A)^{\frac{2}{3}} x_g^{\frac{4}{3}}.$$

The condition that the lines of force leaving the anode all end on the grid and on the space charge may be written

$$\begin{aligned} Q_a &= 2\pi x_g Q/b + \text{space charge} \\ &= 2\pi\alpha x_g Q/b, \text{ say,} \end{aligned}$$

where α is a parameter to be determined by experiment, usually not much greater than unity.

From the first, second and fourth equations we get

$$v_a + g v_g = (1 + g) v_b,$$

where

$$g = \frac{2\pi\alpha x_a}{b} \cdot \frac{\log (x_a/x_g)}{\log \beta/r}.$$

On substituting for v_b we obtain finally

$$j = 2\pi A \frac{(v_a + g v_g)^{\frac{3}{2}}}{(1+g)^{\frac{3}{2}} x_g}$$

where $A = 2{\cdot}33 \times 10^{-6}$ in practical units.

In those cases where the radius of the filament or of the curled filament exceeds about one-tenth of the radius of the grid it is necessary to apply to the formula just obtained the correction given in the table on p. 18.

As an example a particular receiving triode of which measurements have been taken may be quoted here. In this triode $x_a = 0{\cdot}503$ cm., $x_g = 0{\cdot}23$ cm., $b = 0{\cdot}169$ cm., and we may take $\beta = b/2\pi$ for theoretical reasons. Then on substituting in the formula we obtain

$$g = 6{\cdot}71\alpha.$$

Now, experiment showed that g is actually equal to 6·9; hence we conclude that the quantity α is equal to about 1·03.

Again, the formula for the current yields for an anode voltage of 60 and grid voltage zero the value

$$j = 1{\cdot}31 \text{ mA},$$

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if no account be taken of the radius of the cathode. In fact, the cathode is a curly filament of about 0·54 mm. radius. The correction factor is seen from the table on p. 18 to be about 1·1, which gives

$$j = 1{\cdot}44 \text{ mA.}$$

Actually, the measured current was 1·65 mA. This is not a closely accordant result, but is not unsatisfactory when regard is had to the number of circumstances neglected (such as the finite length of the electrodes) in the derivation of the formulæ.

SOME CONSEQUENCES OF THE FORM OF THE CURRENT EQUATION

In the preceding paragraphs, where we have been dealing with the scalar electric potential in a purely theoretical manner, we have used the letter v in reference to absolute values of the potential. In what follows we shall extend the results into relations wherein experimental voltages due to batteries are solely concerned, and shall therefore use the letter e instead of v.

In some respects the most remarkable feature of the mathematical results now reached is the fact that the current through the triode is expressible as a function of $e_a + ge_g$. Of course, it was obvious without any investigation that the current must be expressible in the form

$$i_a = F(e_a, e_g);$$

but the elucidation of the mode of association of the variables e_a and e_g is of considerable mathematical and physical importance. This point has not waited for theoretical discovery, however; it was found empirically by Langmuir (*Proceedings of the Institute of Radio Engineers*, p. 278, 1915), who showed that the lower parts of the characteristic curves of his pliotrons followed the equation

$$i_a = A'(e_a + ge_g)^{\frac{3}{2}}.$$

H. J. van der Bijl has also given experimental evidence of the truth of the theorem in the case of triodes of his own design in the *Proceedings of the Institute of Radio Engineers*, April, 1919. The latter has shown, besides, that the lower values of the currents in his tubes follow the equation

$$i_a = A'(e_a + ge_g + e_o)^2.$$

It is possible to find any number of equations of the type $i_a = A'(e_a + ge_g + e_o)^n$ by choosing suitable pairs of values of the

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parameters e_o and n, but Langmuir's equation has the advantage of possessing a physical reason for the appearance of the index $\frac{3}{2}$, namely, the space charge phenomenon. The form $F(e_a + ge_g)$ includes both of the above formulæ, and has infinite other possibilities, and it appears to be applicable over a greater range than Langmuir's equation, which cannot hold good so far as the point of inflection in the familiar characteristic curves of i_a plotted with values of e_g as abscissæ. But before discussing these and before exhibiting some practical applications it is necessary to point out some of the mathematical consequences of the form of the function.

In the first place it is evident that many of the statements on pp. 20, 67, 6?, concerning the general theory of electric shielding apply immediately to the electron current that passes through the tube when the circuit is completed outside and a suitable voltage applied. Within limits any desired current smaller than the saturation current can be produced by a wide variety of values of e_a and e_g; if, for example, $g = 20$, 100 volts on the anode with the grid at zero voltage is equivalent to 120 volts on the anode with — 1 volt on the grid, and to 80 volts on the anode with + 1 on the grid. In fact, we may say that a principal function of a triode is to multiply the grid voltage by g, transfer it to the anode circuit, and superpose it on the anode voltage. We shall call this total voltage the "lumped voltage" and give it the symbol e_l. The current equation is then

$$i_a = F(e_l).$$

The lumped voltage may now be taken as a new independent variable and the current curves plotted with values of e_l as abscissæ.

Let us take the family of curves in Fig. 9 and transform them to the new variable. It is first necessary to find g from the curves. An easy way is to draw first any line PQRS to mark points of equal currents on the different curves of Fig. 9; then set up ordinates p_op, q_oq, etc., to represent to scale the anode voltage of the respective curves, and draw the best straight line through the points p, q, etc., to cut the axis in z. Since this line relates to constant current, the value of $e_a + ge_g$ must be constant along it, so that a fall in e_a is made up by g times the increase of e_g. Thus the gradient of the line, reckoned on the voltage scales, is the value of g. For example, supposing the final line goes through p and

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that the length p_0 z represents 20 volts on the grid, the value of g is 250 volts ÷ 20 volts = 12·5.

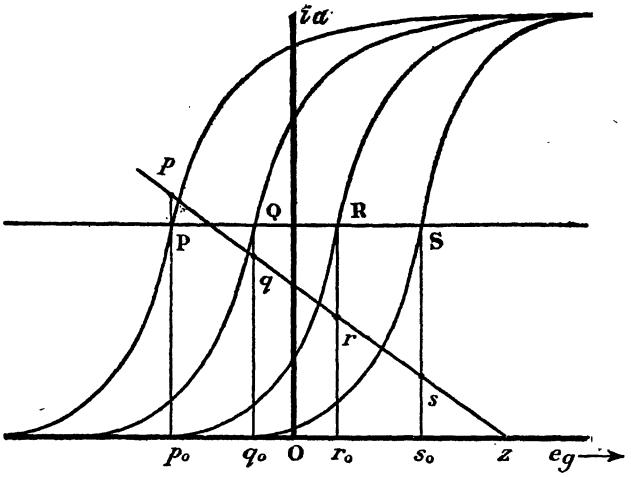

FIG. 9.

The next step consists in calculating the value of $e_a + ge_g$, that is, e_l, for a number of points on the curves of the family, either arithmetically or graphically. The latter method is shown in Fig. 10, where one of the curves is taken aside for the sake of clearness. First the sloping line through O is drawn parallel to the line through z in Fig. 9. The ordinates of this line are g times the corresponding grid voltage. Then a line is drawn through q with constant ordinates equal to the anode voltage of the curve, and ordinates are drawn through any points such as Q, T. Evidently

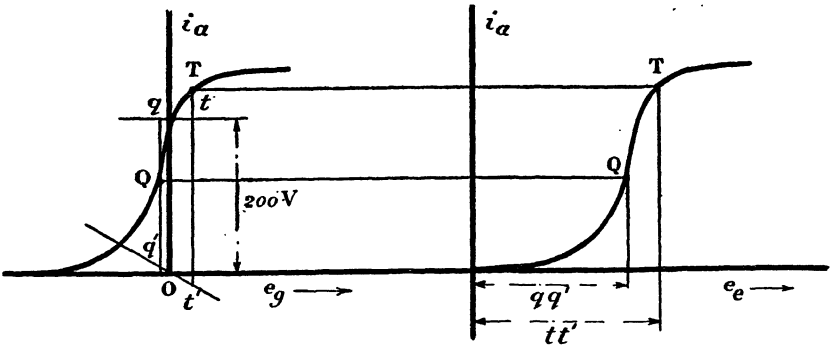

FIG. 10.

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the intercepts between the voltage lines, such as qq′ and tt′, are the algebraic sum of e_a and ge_g, and therefore give values of e_1. The curve sought is now obtained by co-ordinating values of current at Q, T, etc., with the new abscissæ qq′, tt′, etc.; this is carried out on the right-hand side of Fig. 10.

When this process is applied to all the curves of the family in Fig. 11 the result is the nearly perfect single curve of Fig. 12. In this one curve is contained all the information given by the original family of curves. It may be called the lumped characteristic curve of the triode for the particular filament current in use. It is found that the nearly straight portions of the $i_a e_g$ curves of most forms of triode coincide perfectly in the lumped characteristic, but the knees fit together less closely. Also, below a certain

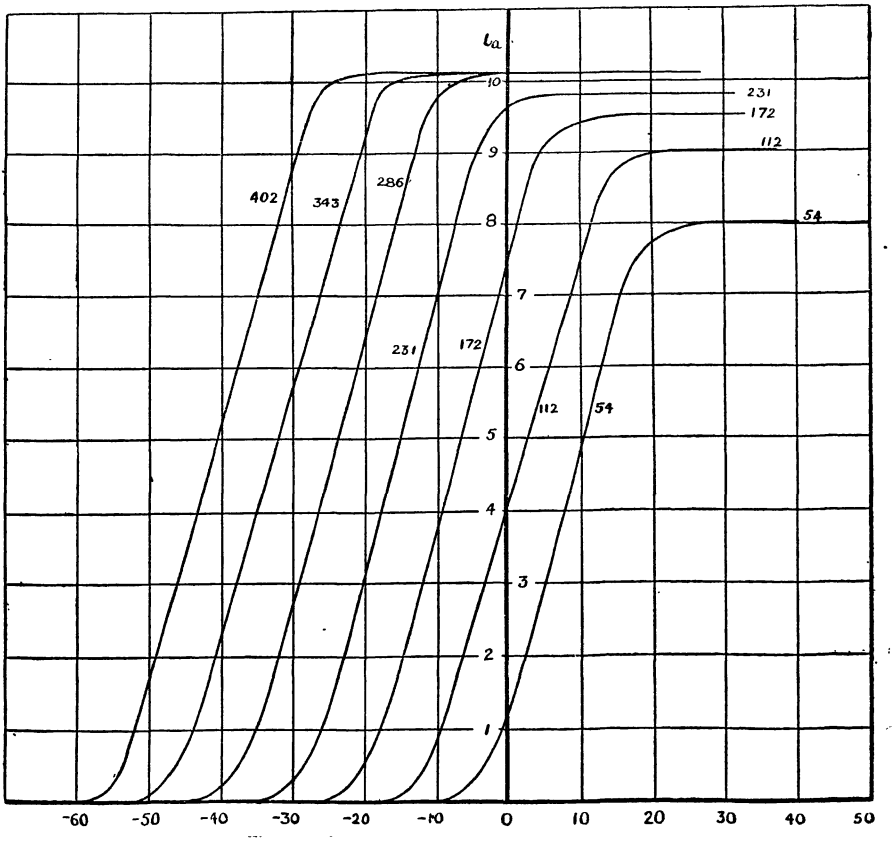

FIG. 11.

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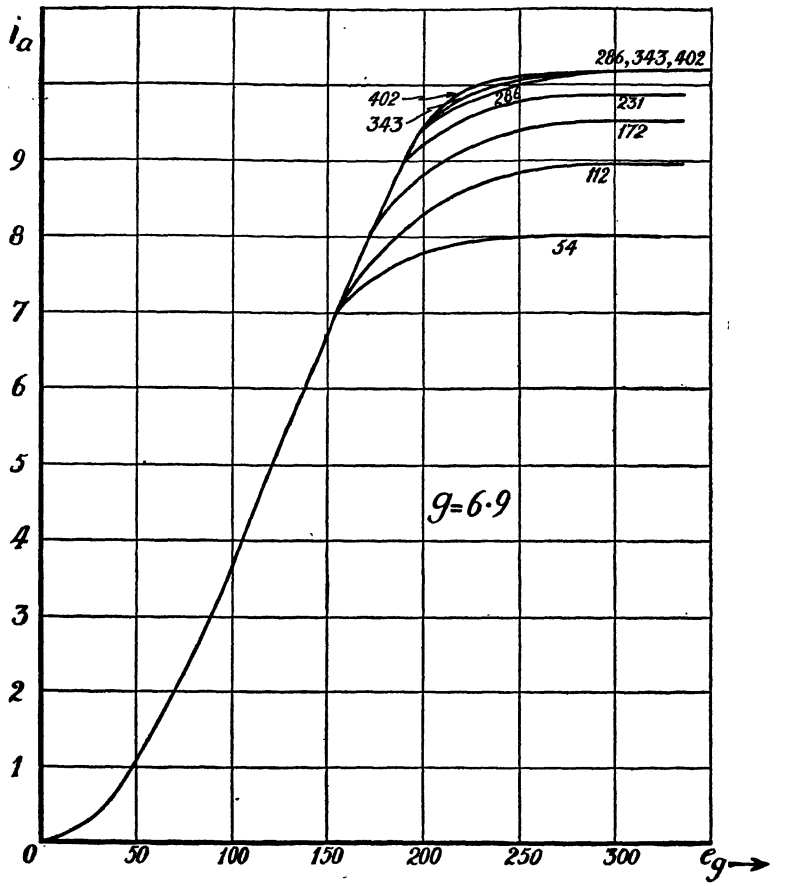

FIG. 12.

anode voltage the saturation currents take lower and lower values, with the result that we obtain the forked portion of Fig. 12.

A further mathematical consequence of the form of our equation is that a simple relation exists between the partial differential coefficients of i_a with respect to e_a and e_g regarded as independent variables. From

$$i_a = F(e_l)$$

we derive

$$\frac{\partial i_a}{\partial e_a} = \frac{di_a}{de_l} \cdot \frac{\partial e_l}{\partial e_a} = \frac{di_a}{de_l}$$

since

$$e_l = e_a + g e_g.$$

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Similarly $$\frac{\partial i_a}{\partial e_g} = \frac{di_a}{de_l} \cdot \frac{\partial e_l}{\partial e_g} = \frac{di_a}{de_l} g.$$

Hence $$\frac{\partial i_a}{\partial e_g} = g \frac{\partial i_a}{\partial e_a}.$$

We shall, for brevity, write h_a for the partial differential coefficient with respect to e_a, and h_g for that with respect to e_g. In this notation the letter h is meant to suggest "increase of anode current," and the suffix a to suggest "per unit increase of anode voltage," and a similar interpretation is given to h_g. In passing, we may remark that this notation is in systematic accord with the use of g_a and g_g for similar partial differential coefficients of grid current with respect to the two voltages, which arise in the course of any complete discussion of the properties of triodes. The differential co-efficient h_a is, plainly, the gradient at any point of the lumped characteristic curve, and h_g is the gradient at any point of any of the $i_a e_g$ characteristic curves. We see that the latter gradient is g times the former whenever the current is a function of $e_a + g e_g$; but this conclusion is not necessarily true when the current does not possess this property.

In the particular form presented by Langmuir's equation

$$i_a = A' e_l^{\frac{3}{2}}$$

we have $$h_a = \frac{di_a}{de_l} = \frac{3}{2} A' e_l^{\frac{1}{2}}.$$

This indicates that h_a would increase continually as e_l increases if the equation were obeyed. As a fact, experimental curves prove that though h_a does at first increase in accordance with the formula yet it is practically constant over a relatively large range, departing further from Langmuir's equation as saturation is approached. It may be mentioned that it is possible to find empirical formulæ to fit the whole curve with moderate success. For example, some triodes are suited by the formula

$$i_a = i_1 [1 + \tanh \{h_a (e - e_1)/i_1\}],$$

where e_1 and i_1 refer to the lumped voltage and the current at the mid-point of the curve; but though such empirical equations may be useful for the purposes of design, they have no physical meaning and explain nothing.

(*To be concluded.*)

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The Transmission of Electro-magnetic Waves Around the Earth.

By THE EDITOR.

OUR experimental knowledge of the variation of the strength of the received signal as the distance from the transmitting station is increased is due almost entirely to the work carried out in 1910 and 1913 by the Radio Department of the United States Navy under the direction of Dr. Louis Austin. Previous experiments had been made by Duddell and Taylor, but only over relatively short distances. The results obtained in the U.S. Navy experiments are usually expressed by the well-known Austin-Cohen formula. For relatively short distances over the sea, the received current varies inversely as the distance, as it would if the earth were a perfectly conducting plane and the atmosphere a perfect and limitless dielectric, but as the distances become greater the received current falls off more rapidly and an exponential factor has to be inserted in the formula for the received current. Austin found that although the transmission at night was usually better than that during the day, it was far more erratic and was therefore discarded in calculating the formula which best represented the observed results. Cohen found that the exponential factor that gave the closest approximation to the 1910 results was $\epsilon^{-\frac{0{\cdot}0015d}{\sqrt{\lambda}}}$ where d is the distance, and λ the wave length, both in kilometres. Although, owing to the difficulties of the measurement, to the variableness of the received signal even when the distance is unchanged, and to the limited range of distance, Austin's 1913 results when plotted leave one in some doubt as to the curve which best represents them. Cohen's exponential index gives good average results up to a distance of 2,000 miles. Turning to the mathematical investigation of long distance transmission, one finds that it is a problem of such enormous difficulty as to call for prolonged research on the part of some of the leading mathematicians. The assumptions usually made have been that the earth is a perfectly conducting sphere, and the atmosphere a perfect dielectric of boundless extent. It is important that this

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problem should be solved and the results compared with the experimental observations in order to determine to what extent the transmission over great distances involves conditions of the earth or of the atmosphere other than those assumed in the mathematical investigations.

The late Henri Poincaré and Professor Nicholson published solutions in 1910; Professor Macdonald in 1914 and March and Rybczynski in 1912 and 1913 respectively. In 1915 Professor Love pointed out that the work of the two last named was fundamentally unsound. Unfortunately the results obtained by Nicholson and Macdonald were not in agreement and so the matter stood in a very unsatisfactory condition until 1918 when the problem was investigated by Dr. G. N. Watson. The results of his analysis are embodied in two papers of the greatest importance communicated to the Royal Society, one in 1918, entitled "The Diffraction of Electric Waves by the Earth," and the other in June of the present year, entitled "The Transmission of Electric Waves Round the Earth." In the September number of the *Philosophical Magazine* Dr. van der Pol gives a physical interpretation of the former paper and substituting suitable numerical values in the formulæ, compares the calculated results with the results of Austin's observations. A brief account of his work was given by Dr. Watson himself in a paper before *Section A.* of the British Association at Bournemouth.

In the first paper he solves the problem of the perfectly conducting earth and limitless ideal dielectric, and obtains a result in substantial agreement with Nicholson and Macdonald. He points out the causes of the discrepancies and the limits of the validity of the various assumptions. An investigation of the effect of the earth having resistance shows that any effect is very small, even for dry earth, with long wave lengths. Watson obtains for the index of the exponential factor $-0{\cdot}00376d/\sqrt[3]{\lambda}$ and, moreover, finds that instead of being inversely proportional to $d\lambda$, the received current should be inversely proportional to $\sqrt{\sin\theta}\,\lambda^{7/6}$, where θ is the angle subtended at the centre of the earth by the distance d. Now, as Dr. van der Pol points out, some of the received currents measured by Austin over distances of about 6,000 miles are 2,000,000 times as great as the values calculated by Watson's formula. Hence, it must be concluded that long distance radiotelegraphy cannot be explained on the assumption that the earth is surrounded by a perfect dielectric of boundless extent. A great

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many phenomena of radiotelegraphy suggest that the upper atmosphere is ionised and acts as a partial conductor.

In his second paper, therefore, Dr. Watson has investigated the effect of a concentric conducting layer forming the upper limit of the atmosphere. His analysis leads to the striking result that Austin's experimental and empirical formula is obtained if the ionised layer has a well-defined lower surface at a height of about 100 km. and has a specific resistance of $6{\cdot}95 \times 10^5$ ohms per centimetre cube. With this reflecting upper layer the index of the exponential term in the formula for the received current contains the square root of the wave length, in agreement with the Austin-Cohen formula, whereas the pure diffraction theory leads to the cube root of the wave length.

The two papers of Dr. Watson mark an epoch in the study of long distance radiotelegraphy and may be regarded as bringing to a most satisfactory conclusion a discussion which has exercised the minds of many of the leading mathematicians.

The British Association Meeting at Bournemouth.

(*Continued from page* 42.)

A Method of Using Two Triode Valves in Parallel for Generating Oscillations.

By W. H. ECCLES, D.Sc., and F. W. JORDAN, B.Sc.

Paper read before Section G (Engineering) of the British Association Meeting.

IN the typical method of using a three-electrode tube or "triode" for generating electrical oscillations, the connections are as shown in Fig. 1. The oscillations in the closed inductance-capacity circuit, sometimes called a flywheel circuit, are sustained by unidirectional pulses of current through the anode circuit, that is, through that external circuit of the tube which begins at a terminal of the filament and ends at the anode. This circuit includes a high voltage battery, which is the ultimate source of the energy of the oscillations. The unidirectional pulses are produced in

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correct time phase by the action of the oscillations themselves on the grid circuit by means of the coupling between the coil in the closed circuit and a coil in the grid circuit.

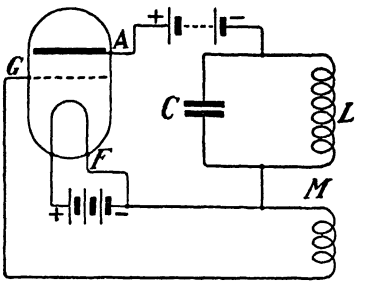

FIG. 1.

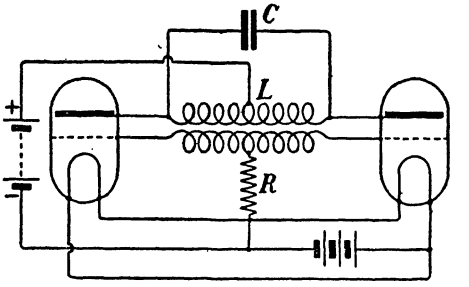

FIG. 2.

When two or more triodes are used they are in the prevailing practice connected in parallel. It is known that unless special care is taken in selecting the tubes and in adjusting their normal grid voltages this connection does not in general give an output double that of a single tube. Moreover, if the coupling is made too close, as is often the case, the variations of the grid voltage may be so great as to carry the representative point in the characteristic diagram on to the straight horizontal parts of the curves, with the consequence that harmonics are produced, accompanied by a lack of symmetry in the oscillations generated.

More symmetrical oscillations could be obtained if the flywheel circuit were acted upon by a triode and high-voltage battery symmetrically in every half-period. The improvement to be described consists in arranging two tubes so as to fulfil the last stated condition. One way of doing this is to join the grids of the two tubes by a coil which is linked by means of its mutual inductance to the oscillating circuit. This method of joining the grids is shown in Figs. 2 and 3. This mode of connection causes the potential of each grid, and, therefore, the resistance of each tube, to vary in opposite directions, that is, causes the resistance of one tube to increase, while that of the other diminishes—with a definite phase relation to the oscillations.

In Fig. 2 the anode circuits of the tubes are in parallel, and are connected in series with a high-voltage battery. They are associated with the flywheel circuit so that increase of one anode current applies to the flywheel circuit a stimulus in one direction,

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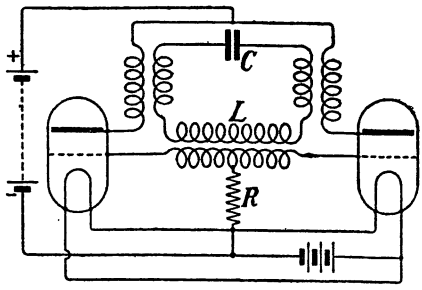

FIG. 3.

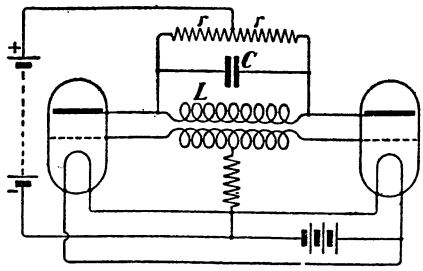

FIG. 4.

and increase of the other anode current applies a stimulus in the other direction. In the result the variations of both anode currents are effected in correct phase relation to maintain the oscillations of the flywheel circuit, an impulse being applied first by one tube and then by the other in successive half-periods.

In Fig. 2 the coupling between the two anode circuits and the oscillatory circuit is direct. Fig. 3 shows a method in which the anode current acts by mutual inductance on the oscillatory circuit. In both figures R is a large resistance which acts as a grid leak, and should be chosen so as to keep the grids at a voltage found advantageous by trial. A method in which resistance coupling is employed is indicated in Fig. 4. This has its advantages in certain laboratory applications. In Fig. 5 a method employing condenser coupling is shown. Here, again, R indicates a grid leak. The condensers C_1 and C_2 need not be of any particular capacitance; they are chosen by trial, and their variation has very little effect upon the frequency of the oscillations.

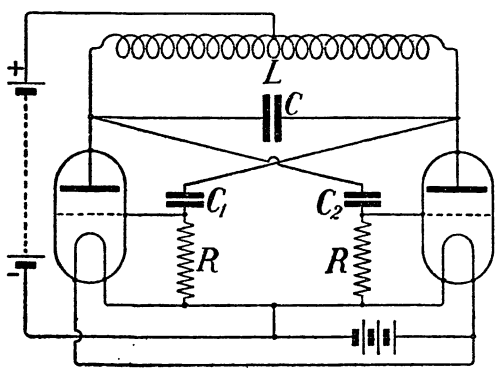

FIG. 5.

It is clear that, instead of using two triodes, the symmetrical action could be obtained by using one tube possessing, for example, a single plate, two grids and two filaments, or, alternatively, a single filament, two grids and two plates.

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It is found that these cross-coupled circuits oscillate more freely than single circuits. They can be operated, for example, by using four or five volts only in the anode circuit with ordinary receiving B.T.-H. triode valves.

The devices just described were the subject of a patent, number 6,090/1918, taken out by the Admiralty, and the description is now published by permission.

The Three-Electrode Thermionic Valve as Alternating Current Generator.*

By Professor C. L. FORTESCUE.

1. Introductory.

THIS paper deals mainly with work done during the war in the W/T Department of H.M. Signal School, at Portsmouth, which constitutes the instructional and experimental centre for all matters pertaining to naval wireless telegraphy. The paper has been prepared in collaboration with the Superintendent of Signal Schools and his staff, has been submitted to the Admiralty, and is now published with the Board's approval.

Thermionic valves were used in the Naval Service for the generation of high-frequency currents of small amplitude for reception by the "heterodyne" or beat method in 1914. De Forest's "Audion" valves were used, and the circuits were made up from existing Naval Service apparatus. Later sets used for the same purpose were made by the Marconi Company, the valves employed being those designed by Captain H. J. Round. In both cases the maximum high-frequency current was in the neighbourhood of 50 milliamperes.

During the spring of 1915 experiments were carried out with a transmitting valve of Captain Round's design. This valve was of the same general construction as those used with the small heterodyne sets. The filament consisted of a fine platinum wire coated with lime; the grid was made of nickel wire gauze, and a nickel positive electrode was supported by its natural springiness against the glass walls of the tube. The vacuum was not high, and no appreciable bombardment of the electrodes was carried out during the exhausting process, this being impossible owing to the large positive electrode being in contact with the glass walls of the tube. With this tube a high-frequency power of from 40 to 50 watts could be obtained. Experiments under actual signalling conditions were carried out, and some

* Paper read before Section G, of the British Association, slightly abbreviated.

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surprisingly long ranges were obtained. On one occasion one of H.M. destroyers received comfortably readable signals when off the coast of Northumberland, and when the high-frequency current in the aerial in H.M.S. *Vernon* at Portsmouth was only 0·6 amperes.

Considerable difficulties were, however, experienced on account of the lack of proper heat treatment of the valve in the course of the exhaustion, and the valves were not regarded as being sufficiently reliable to enable them to be used in ship installations.

At about this time the French, too, were experimenting with valve transmission, with a view to the development of wireless telephony.

Towards the end of 1915 some transmitting valves of the "Oscillion" type were obtained from America by the Admiralty. These valves were exhausted to a higher degree than the Marconi valves, and gave correspondingly better results. But the uncertainty of the supply, and the still far from perfect results obtained, made it evident that the requirements of a naval W/T set using transmitting valves could not yet be met.

In the spring of 1916 a "Pliotron" valve, made by the American General Electric Company, was purchased by the Admiralty for experimental work. This valve, which was similar in construction to those described in the *General Electric Review* of May, 1915, and September, 1916, had been very thoroughly exhausted. It was normally worked with the tungsten positive electrode at a bright red or even yellow heat, and but for one small defect was probably the equal of any valve made up to the end of 1918. High frequency currents of from 8 to 10 amperes were obtained in an aerial of about 5 ohms resistance, and with only about 2,000 volts available for the supply to the positive electrode. Had a higher voltage supply been available there is little doubt but that the high-frequency power generated could have been doubled. On the only trial carried out for maximum range under signalling conditions communication was established between H.M.S. *Vernon* at Portsmouth and H.M. W/T station at Gibraltar. This was in June, 1916, and at the time was second in range obtained with an oscillating valve only to the famous wireless telephone trial between Arlington, U.S.A., and the Eiffel Tower.

It was recognised that, although the "Pliotron" valves as then developed could not be manufactured on a scale sufficiently large to meet naval requirements, the elements of successful development were present, and exhaustive trials and experiments were continued by the Experimental W/T Staff of H.M.S. *Vernon*. The results of these experiments, together with the information already published in the technical and scientific journals (principally American), enabled a fairly complete theory of the action of both the circuits and the transmitting valves to be worked out. This theory has formed the basis of all the subsequent designs.

Early in 1917 the first attempts were made to manufacture transmitting valves in this country to meet naval requirements. These attempts were undertaken by the General Electric Company at their lamp works at Hammersmith, in collaboration with the Naval Experimental W/T Staff.

Previous to this, although the advantages of valve transmission were

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fully realised, there had been no demand for additional lines of communication, the requirements of which could not be met by the existing arc or spark installations; nor was there any demand for the replacement of the latter by valve transmitters. Consequently, although the necessary conditions were investigated as fully as possible, no earlier steps were taken to start British firms on the manufacture of the larger valves, their staffs being already fully engaged on war work.

By a fortunate coincidence, however, the construction of these valves just preceded an urgent demand from the Grand Fleet for a valve transmitting set. The designs were worked out, and eight sets were put in hand in the W/T workshops in H.M.S. *Vernon*. The first two of the sets were despatched to the Grand Fleet on the night of Good Friday, 1917, within six weeks of the demand for the sets arising. Some two months elapsed, during which lengthy trials were carried out. On the strength of these trials it was decided to fit similar sets in a considerable number of ships. Contracts were placed with various instrument-making firms, and within one month the first of these sets was on its way north, not complete in every detail certainly, but sufficiently complete for satisfactory service.

Meanwhile numerous experiments were conducted by the W/T staff of the Admiral Commanding Reserves with Marconi valves installed in W/T stations located round the coasts of the British Isles. These experiments gave useful information, and showed that results could be obtained even with valves that were only partially exhausted. In particular they demonstrated the advantage of working with high voltages for the supply to the positive electrode.

The success of the first valve transmitting sets in the Grand Fleet led quickly to a demand for other sets of greater power. In the autumn of 1917 a larger set was designed to work from the power supply of existing spark apparatus. The trials of this set were carried out during the winter of 1917—1918, the details of the design being finished early in 1918. The apparatus was being fitted in ships as it became available throughout the whole of the summer of last year. To a great measure the success of this set was due to the type of aerial tuning inductance employed. This coil was designed by the W/T staff at Portsmouth primarily for use with Poulsen arc sets. The work previously carried out by this staff in connection with the design of inductances may be said, in fact, to have contributed more to the success of the valve sets than any other single item, except perhaps the design of the valves themselves.

Whilst the parts of this more powerful set were being manufactured yet higher power sets were being experimented with for use on board ship and in the Admiralty shore stations. Outputs and ranges almost equal to those of the smaller Poulsen arcs were obtained, and the many advantages of the valve transmitter pointed to the certainty of it replacing the arc in the near future for all purposes except in the very highest-powered land stations.

Valve transmitting sets also had their application in the other services—the Army and the Air Force. The direction and the nature of these applications have already been described by Colonel Cusins, R.E., and by Major

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Erskine-Murray before the Wireless Section of the Institution of Electrical Engineers.

A similar development was of course also taking place in France and in America. Valves of very considerable power were being experimented with in France in 1917 under the direction of General Ferrié. In America the development was more in the direction of quantity production of relatively small power tubes for short range telegraphy and telephony work.

Wireless telegraphy and telephony do not constitute the only spheres of utility of the three-electrode valve as an alternating current generator. For laboratory and testing purposes it is rapidly taking the place of all other sources of alternating current where frequencies above about 200 cycles per second are required.

The successful application of the valve transmitters to naval wireless was largely due to the valuable assistance of the following permanent and temporary members of the Naval Experimental W/T Staff, viz., Messrs. W. A. Appleton, B. S. Gossling, H. A. Madge, H. Morris-Airey, and C. M. Sleeman; of Captain J. A. Slee, C.B.E., R.N., formerly on the staff of the Admiral Commanding Coastguard and Reserves; of Captain H. J. Round, M.C., formerly attached to Army Signals, and of Dr. G. B. Bryan, the Assistant Professor of Physics, R.N. College, Greenwich.

2. The Action of the Three-Electrode Valve as an Alternating Current Generator.

The conditions necessary for a three-electrode valve to act as a generator of alternating currents have been investigated by others besides the workers at H.M. Signal School, Portsmouth, notably, Hazeltine * in the *Proceedings of the Institute of Radio Engineers*, has given a very complete investigation of the requirements. Vallauri † has also worked out the critical condition for a few particular cases. Recently Eccles has shown, before the Physical Society of London, a method of investigating the problem by a graphical method.

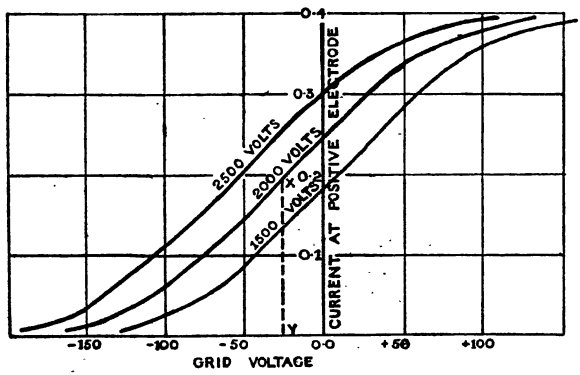

FIG. 2.

The principles of the action of the three-electrode valve itself have already been described on many occasions. For the purpose of generating alternating currents a highly exhausted valve is generally used. Fig. 1 shows the construction of such a valve.

* *Proc. Inst. Radio Engineers*, April, 1918.

† *L'Elettrotecnica*, January 25th and February 5th, 1917.

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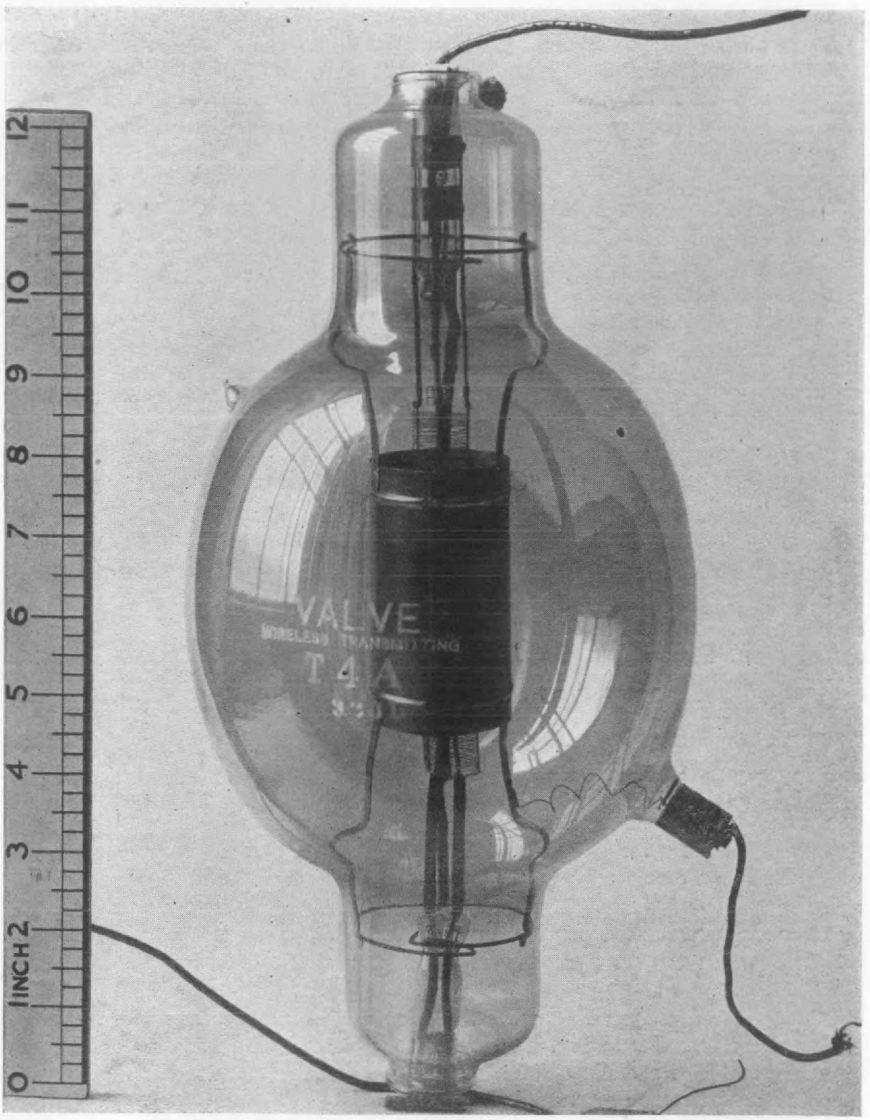

FIG. 1.

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Characteristic curves showing the control exercised by the grid electrode in a valve of this type are shown in Fig. 2. From these curves it is observed that, with the grid 100 volts or more negative to the filament, it is only with high voltage on the positive electrode that the current at this electrode is appreciable. As the grid becomes more positive, the current at the positive electrode gradually increases to a more or less clearly defined maximum value. After this maximum has been reached any further increase of the positive voltage of the grid will lead to a decrease of the current at the positive electrode, because of the diversion of an appreciable portion of the electron stream to the grid itself.

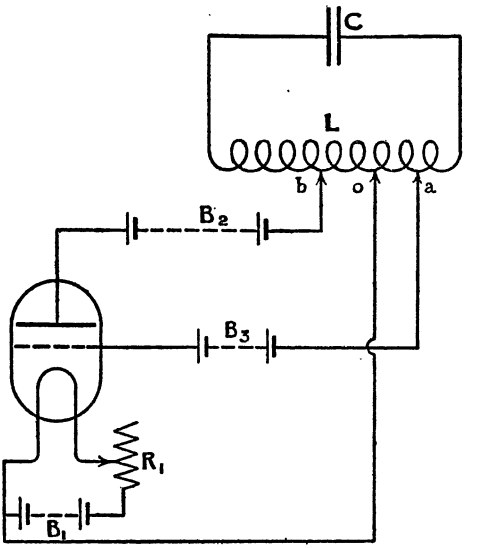

FIG. 3.

There are many ways of connecting up a three-electrode valve of this kind to an inductance-capacity circuit so as to maintain oscillations. One of the simplest is that shown in Fig. 3. Here C is the condenser and L is the inductance. The filament of the valve is heated by a battery B_1, the heating current being controlled by the resistance R_1. The filament is directly connected to a point O on the inductance. The positive electrode is connected to a point b on the inductance through a battery or other source B_2. The grid is connected to a point a on the inductance, on the opposite side of the point O to that of the point b, with a battery B_3 in series.

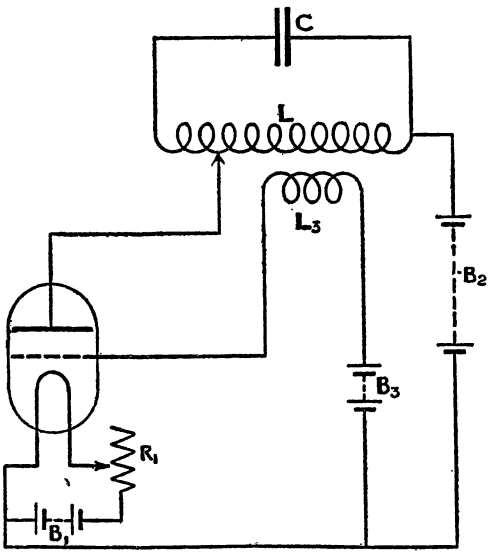

FIG. 4.

The filament current and the voltages of the batteries B_2 and B_3 are adjusted so that the steady conditions correspond to a point X on the curves of Fig. 2.

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Assuming that there is no time lag in the adjustment of the electronic stream to the changes of grid voltage, as should be the case theoretically for all frequencies up to ten million or more per second, then this arrangement of a valve with a capacity-inductance circuit becomes an alternator of frequency depending upon the natural frequency with which the current in the circuit *LC* will oscillate. By adjusting the capacity and the inductance to suitable values this frequency can have any desired value from at least ten million cycles per second downwards to frequencies of 250 cycles per second, or even less, if somewhat bulky apparatus is not objected to.

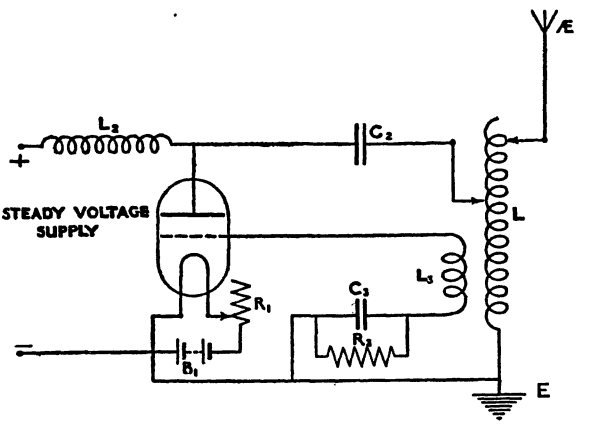

FIG. 5.

The circuit arrangement of Fig. 3 is but one of many possible ones. For instance, Fig. 4 shows a very commonly used circuit. Here the grid is influenced by the induced E.M.F. in the coil L_3 instead of by the induced E.M.F. in a part of the main coil L, as in Fig. 3. Fig. 5 shows a very convenient circuit arrangement for a valve transmitter for wireless telegraphy. This arrangement is in principle the same as Fig. 4. The addition of the condensers C_2 and C_3, and of the inductance L_2, are for reasons of practical convenience rather than difference of principle.

(*To be concluded.*)

A New German Association for Applied Physics.

At a meeting held in Berlin on June 6th it was decided to found a new Association for Applied Physics. It is proposed to (1) hold meetings at which papers will be read; (2) issue a periodical with abstracts and original papers; (3) issue an index similar to the *Chemical Zentralblatt;* (4) hold an Annual Convention in different towns; (5) consider educational matters and the foundation of scholarships. The first council includes, among others, Profs. Warburg, Kurlbaum, Gerdien, and Wagner. —*Jahrbuch der Drahtlosen Telegraphie, August*, 1919.

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Review of Radio Literature

1. Abstracts of Articles.

NOTE.—*It is intended to devote the space in this section of the* RADIO REVIEW *to as complete a review as possible of the published literature of radiotelegraphy and telephony, and kindred matters. The more important of these papers and articles will be given in abstract, while, for the remainder, references will be given, accompanied by one or two lines to indicate the contents of the article. In this way it is hoped to obtain a complete monthly record of the progress of the science, and of the latest developments and inventions relating thereto, that should be of considerable value to all research workers and students of the subject.*

19. ON MEASUREMENT OF SIGNAL STRENGTH. W. H. Eccles. (*Proceedings Inst. Radio Engineers*, 7, p. 267, June, 1919.)

Considerable use has been made of the "shunted-telephone" method of measurement of received signal strength, but confusion has sometimes arisen between the audibilities $A = \frac{R+S}{S}$ and $A' = \frac{Z+S}{S}$, calculated from the results obtained. (R and Z = telephone resistance and impedance respectively, corresponding to note frequency in use, and S shunt resistance.)

The author develops the vector diagrams for the circuit, and deduces curves showing the relation between A or A' and the current "strength-ratio," $a = \frac{\text{Detector Current}}{\text{Telephone Current}}$. From a consideration of the conditions obtaining when the method is used for the comparison of signal strengths of the same note frequencies, it is shown that the quantity $a \cos \phi$ is proportional to the square of the aerial current, provided that the efficiency of the detector remains constant. From the vector diagrams it is then seen that this quantity

$$a \cos \phi = \frac{a^2 (S^2 + Z^2) - S^2}{2aZS}.$$

For small values of S (loud signals) this reduces approximately to $a \cos \phi = \frac{aZ}{2S}$, and for faint signals to $a \cos \phi = \frac{(a^2-1)\, S}{2aZ}$. It appears from experimental curves given by Van der Pol that, taking the power ratio, $a \cos \phi$, as the measure of the signal strength, the detector appears not to be losing its efficiency with weak signals as rapidly as has usually been supposed.

An alternative method of measuring the signal strength is also described, in which a local buzzer of adjustable pitch is employed to provide a comparison signal of known and adjustable intensity. The method is also

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applicable to C.W. reception. L. W. AUSTIN, in the discussion on the paper, supplies additional information relative to the use of the telephone resistance or impedance in the calculation of the audibility factors.

20. A NEW METHOD OF USING CONTACT DETECTORS IN RADIO MEASUREMENTS. L. W. Austin. (*Proceedings of the Institute of Radio Engineers*, Vol. VII., p. 257, June, 1919.)

An arrangement of crystal detector for radio-frequency measurements is described. The crystal detector, in series with a galvanometer, is shunted by a non-inductive resistance. This complete unit may be calibrated against a small low-reading hot-wire instrument by reducing the value of the non-inductive shunt. The complete shunted detector can then be used for other shunt values by dividing the sensibility by the shunt ratio. A table of sensibility and maximum working current is given for various shunt resistances.

21. MEASURING THE CAPACITY OF VACUUM TUBES. (*Everyday Engineering Magazine*, 7, p. 299, August, 1919.)

A simple method is described in which the grid-filament capacity is measured, under working conditions of the tube, by determining the wave length of a closed circuit with and without the valve in parallel with the tuning condenser.

22. COUPLING FOR RADIO CIRCUITS. E. Bellini. (*British Patent* 126978, February, 1916.) *

The coupling of two oscillatory circuits is dealt with, and the advantages are pointed out of a combined magnetic and electric coupling in order to secure oscillations of a single frequency.

23. COUPLING FOR WIRELESS TELEGRAPH APPARATUS. J. Bethenod. (*British Patent* 128575, March, 1918.)

This patent relates to a special means of coupling a high frequency alternator to a transmitting aerial. The alternator is provided with a number of separate windings which are coupled to the aerial circuit by separate transformers. These transformers may have iron cores in certain cases.

24. APPLICATIONS OF THE VALVE. (*La Nature*, 47, pp. 117—126, August, 1919.)

The latest developments of valve apparatus are considered in three classes: Complete stations; Amplifiers; and apparatus for special research or investigation. In the first, and second, descriptions of some French Army C.W. sets are given, while the third deals with laboratory apparatus.

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* See footnote, p. 49.

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French Army Radio Sets.—The most generally used set since 1917 (type C.A.) has a three-valve transmitter and a crystal or valve receiver. One valve of the transmitter acts as a hetorodyne when receiving. Twelve watts are used for filament heating and about 20 watts (at 350 volts) for the plate circuits. Using an umbrella aerial 27 metres high a range of 250 km. has been obtained. Total weight of set with cells = 160 kg. Weight of set alone 50 kg.

The most recent combined transmitting and receiving sets have six valves, three used for transmission and three for reception; while among receiving sets three valves are generally used, one detecting and two low frequency amplifying; or with four valves, one for H.F. amplification, one detecting, and two low frequency amplifiers. For a 1 kw. radiotelephone set, six large valves are used, with a H.T. voltage of 1,000 and a filament voltage of eight. The microphonic control is effected on the grids of the transmitting valves, through a two-valve low frequency amplifier. For speech communication with aeroplanes a range of 120 km. has been obtained with this set and a telegraphic range of 1,000 km.

Under the heading of amplifiers descriptions are given of high and low frequency amplifiers using four, six or eight valves with inductive or resistance capacity couplings.

Wavemeter standardisation.—In connection with the standardisation of wavemeters, the arrangement devised by H. Abraham is described (see RADIO REVIEW, Abstract No. 1). Two valves V_1 V_2 are used, fed from common filament and plate circuit batteries as indicated in Fig. 1. The coupling between the valves is provided by the two variable condensers C_1 C_2. By adjusting these condensers the fundamental frequency of the oscillations can be controlled. Harmonics up to the 150th can be obtained, enabling absolute frequency determinations to be made up to a frequency of 150,000 (λ = 2,000 metres) by direct comparison with a tuning fork of frequency 1,000.

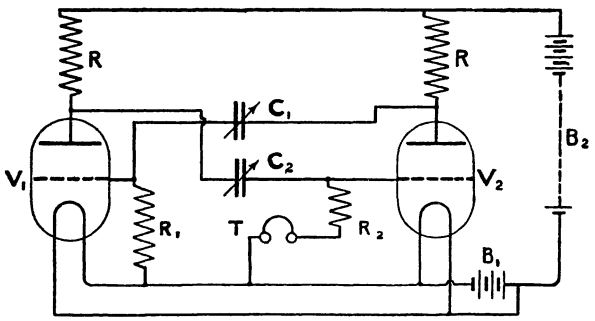

FIG. 1.

Interference prevention.—An arrangement for this purpose attributed to Lieutenant Levy, consists of a double application of the heterodyne principle. The incoming oscillations from the receiving aerial are first heterodyned to a frequency of 10,000, and this resultant frequency again heterodyned to a musical frequency of about 700. The effect of atmospherics can by this means be greatly reduced.

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25. Apparatus for the Radio Laboratory. M. B. Sleeper. (*Everyday Engineering Magazine*, 7, pp. 357—359, September, 1919.)

Constructional details are given for a laboratory wavemeter with views of the complete instrument, and calibration curves.

26. Air Fans for Driving Electric Generators of Aeroplanes. G. F. Gray, J. W. Reed, and P. N. Elderkin. (*Journal of the Franklin Institute*, 188, p. 270, August, 1919.)

The authors describe the method employed by the radio development section of the United States War Department in testing air fans for driving the electric generators used for radio communication on aeroplanes. The various types of fans are discussed at some length and also the difficulties met with in designing a fan to run at constant speed with widely varying aeroplane speeds.

27. Research Work of the General Electric Company in the Great World War. J. R. Hewett. (*General Electric Review*, 22, p. 601, August, 1919.)

This article describes in detail the work of the General Electric Company, U.S.A., and includes references to and photographs of high-frequency machines and other radio apparatus of recent design. The 200 kw. 25,000 cycle high-frequency alternator of the Alexanderson type installed at the New Brunswick (N.J.) radio station, is described and illustrated. The various continuous wave valve transmitting sets used with the United States Army in France are also described. An interesting oscillogram is given of the control current of the Alexanderson magnetic amplifier microphone and the resultant current in the New Brunswick aerial taken during a conversation between the U.S. Naval Secretary and President Wilson over a range of 500 miles. This article includes photographs of some of the latest types of American "pliotrons," but very little detail of the internal structure can be distinguished.

28. Special Type of Quenched Spark Radio Transmitter. D. G. McCaa. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 409—415, August, 1919.)

A quenched spark transmitter is arranged with a double aerial system, so that the capacity in the highly-damped primary circuit is that between one of the aerials and earth. Experiments are described and oscillograms given showing the spark frequency and radiation characteristics.

29. Discharge-Gap Apparatus. Société Française Radio-Electrique. (*British Patent* 126030, December, 1915.) *

This particular apparatus for the production of electric oscillations consists

* See footnote on p. 49.

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of an evacuated vessel containing a heated filament for cathode, and an anode of mercury or amalgam, capable of emitting vapour.

30. Improvements in Wireless Signalling Systems. The General Electric Company (U.S.A.). (*British Patent* 128682, January, 1918. Patent accepted July 3rd, 1919.)

In wireless signalling systems using continuous waves, amplitude pulsations of the oscillations in the aerial are produced by a series of alternating currents of different frequencies of a lower order than the wave frequency. In the arrangement described in this specification the aerial is excited by a high frequency alternator which is controlled by a magnetic "microphone," or magnetic amplifier. This magnetic amplifier is provided with direct current excitation and in addition with currents drawn from any one of a number of alternators of different frequencies driven from the same shaft as the main high frequency alternator. Multiplex telegraphy may be accomplished in this manner by simultaneous sending with three or more different note frequencies. At the receiving station separate circuits are employed tuned to the different note frequencies in order to obtain the requisite selectivity.

31. The Valve as Oscillation Generator. (*Popular Science Monthly*, 95, p. 142, October, 1919; *New York World*, July 8th, 1919; *Wireless World*, 7, pp. 456—457, November, 1919.)

An important judgment was given in the U.S. District Court, New York, in July, to the effect that Claim 1 of the U.S. Patent No. 803684, held by Dr. J. A. Fleming, and describing his well-known valve, is to be held as covering its use not only as a radio detector, but also as an oscillation generator.

32. A Transmitter Designed to Radiate Waves of Low Decrement. C. L. G. Fortescue. (*Wireless Age*, 6, p. 22, August, 1919.)

The use of a special tuned circuit upon the step-up transformer of a spark transmitter is claimed to enable waves of lower decrement to be radiated.

33. Radiotelephone Development in the Army. N. H. Slaughter, G. F. Gray and J. W. Stokes (Signal Corps, U.S.A.). (*Electrical World*, 74, pp. 340—343, August, 1919.)

A general description of the apparatus developed by the Signal Corps for radiotelephone communication with aircraft. The development of the sound proof helmet for receiving, and microphone transmitters unresponsive to engine noises, are dealt with, and details are given of constant voltage wind-driven generators with vacuum tube regulation.

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34. WIRELESS TELEPHONY. (*Post Office Electrical Engineers' Journal*, 12, p. 101, July, 1919.)

This article deals with demonstrations of wireless telephone apparatus by the Marconi Company. Besides other information as to the working of the sets, it contains the wiring diagrams of the transmitter and receiver,

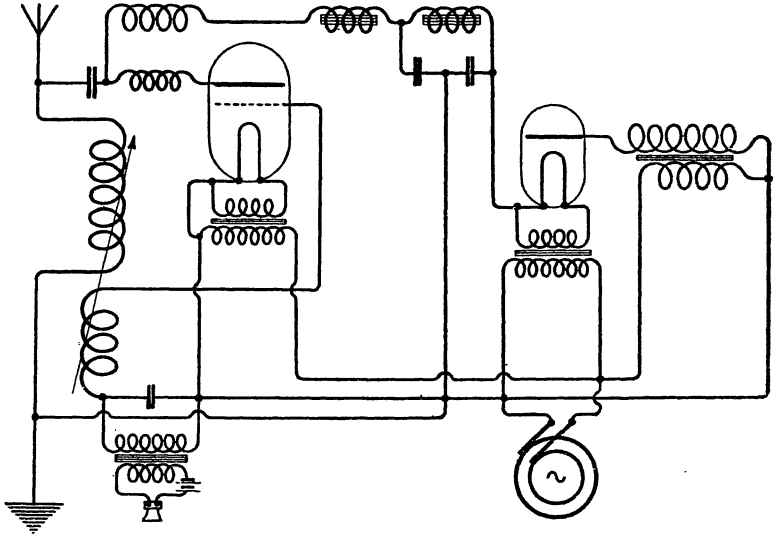

FIG. 2.

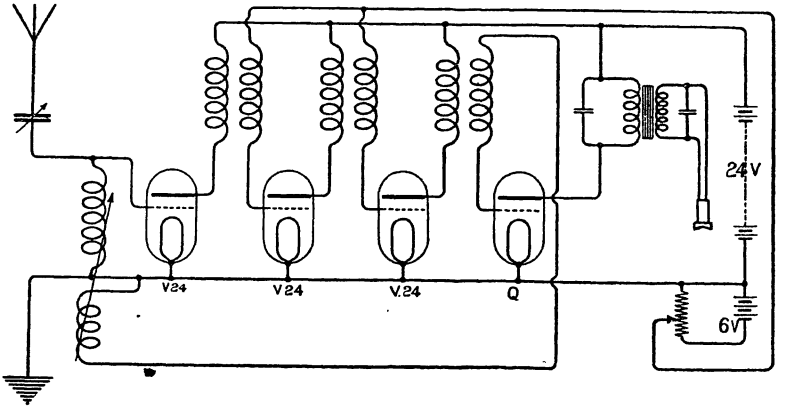

FIG. 3.

which have not previously been published. The transmitting valve is excited from an alternating current supply through a rectifying valve (Fig. 2), while the receiver comprises three radio frequency amplifying valves and one detecting valve (Fig. 3).

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35. Modulating Apparatus for High Frequency Electric Signals. The Western Electric Company (U.S.A.). (*British Patent* 130219, October, 1918. Patent accepted July 31st, 1919.)

An arrangement is described for the modulation of a radio transmitter (such as for speech transmission, etc.) in such a manner that radiation takes place only when the modulating current is acting and not continuously. One such arrangement is shown in Fig. 4. *G* is the source of H.F. oscillations of the " carrier " frequency. This is coupled through T_1 to the common

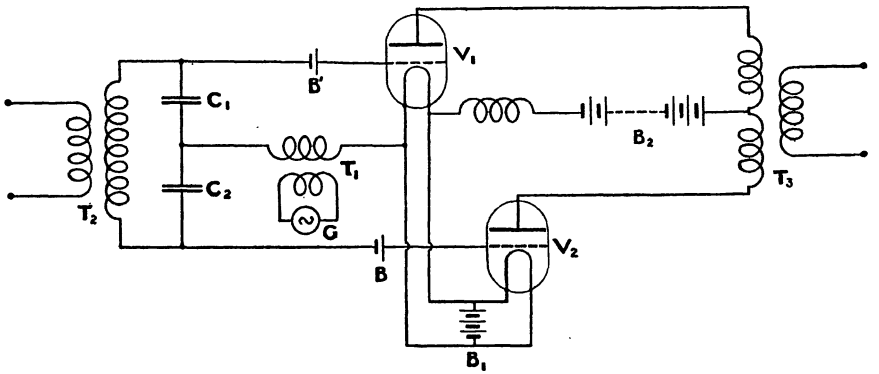

Fig. 4.

grid circuits of modulating valves V_1, V_2. The plate circuits of these valves are coupled through T_3 to the output circuit. The two primaries of T_3 produce opposing effects on the output circuit so that normally no radiation takes place. When modulating current is supplied through T_2 the potentials of the grids of V_1 and V_2 are varied in opposite sense, so that the oscillatory currents through the primaries of T_3 no longer balance, and radiation takes place.

In an alternative arrangement the two valves may be replaced by a differential microphone controlled electromagnetically by the modulating current.

36. Improvements in Vacuum Tubes. G. A. Bauvais. (*British Patent* 130039, August, 1917. Patent accepted July 31st, 1919.)

During the exhaustion of a valve the spiral grid is heated by passing current through it, and the plate is heated by electronic bombardment, using the grid as cathode. In the use of the tube current may also be passed through the grid wire so that the potential difference between any point on the grid and the adjacent part of the cathode is the same at all points along the grid.

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37. IMPROVEMENTS IN VACUUM TUBES. G. A. Bauvais. (*British Patent* 130040, August, 1917. Patent accepted July 31st, 1919.)

This patent describes the use of screens round the supports for the anode and grid in order to prevent deposition of a conducting film on the leading-in seals. Cooling of the electrodes in a high voltage valve may be promoted by making the surfaces large and by covering them with a material of high emissivity.

38. VACUUM TUBES. H. Pilon. (*British Patent* 125945, April, 1918.)

This patent deals with constructional details of vacuum valves, the special feature claimed being the shaping of the anode, so that the filament is in equilibrium under the resultant electrostatic forces.

39. IMPROVEMENTS IN VALVES FOR WIRELESS TRANSMISSION SYSTEMS. C. Hiatt, W. J. Davis, and Edison Swan Electric Company. (*British Patent* 129051, April, 1918. Patent accepted July 10th, 1919.)

The construction of anodes for valves is described. In the particular form dealt with the anode plate has an extension integral with it which may either be embedded directly in the glass stem of the bulb, or pressed round a post similarly mounted. The object of the invention is to obtain an arrangement such that the supports for the anode become heated by conduction from the anode plate during the exhaustion of the tube, thus increasing the facility with which the occluded gases may be removed.

40. ARTOM'S VISUAL RECEIVER FOR DIRECTIVE WIRELESS TELEGRAPHY. (*Wireless Age*, 6, p. 21, August, 1919.)

An arrangement is described for automatically indicating the direction of the received waves on the scale of the instrument. A special form of moving coil galvanometer is employed, energised from the rectified current derived from the two directional aerials, so arranged that its pointer indicates the required wave direction on the galvanometer scale.

Special constructions of vacuum valves are also described, to facilitate the use of valve detectors for this purpose.

41. THE POSSIBILITIES OF CONCEALED RECEIVING SYSTEMS. A. H. Taylor. (*Proceedings of the Institute of Radio Engineers*, 7, p. 261, June, 1919.)

Experiments on various forms of frame aerials are described, and particularly the directive results obtainable with two frames at right angles. Less interference from atmospherics was generally found with this arrangement.

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42. Apparatus for the Concentration of Electric Waves in a Single Direction, or upon a Fixed Point. L. Rota and E. Binetti. (*British Patent* 128624, August, 1917. Patent accepted July 3rd, 1919.)

The apparatus for transmitting and receiving electromagnetic waves in or from a predetermined direction consists of a series of cylinders, or prisms, with their axes lying along the required direction, the cylinders, etc., being connected to each other by transformers, and an end cylinder being connected to the oscillation producing or reception circuit. The specification provides for the enclosing of these cylinder "aerials" inside an additional set of tubes. These tubes may be connected to batteries through resistances and choking coils as necessary. The arrangement is claimed to ensure secrecy in working, and to prevent interference by atmospherics, or by signals intended for other stations, and to prevent absorption and dissipation due to atmospheric electricity.

43. Aerials and Like Radiating and Receiving Conductors. General Electric Company (U.S.A.). (*British Patent* 127675, May, 1916.)

A frame-aerial directive receiving arrangement, comprising a coil of large number of turns wound over damping copper sheets of low impedance. The energy of signals or atmospherics coming from other directions than in the plane of the coil is damped out by the copper sheets.

44. Experiments on Ground Aerials with Their Relation to Atmospherics. C. D. Herrold. (*Radio Amateur News*, 1, p. 11, July, 1919.)

This paper deals with extensive experiments on the various types of ground aerials. A double aerial, with the receiver in the centre, was found to give the best ratio of signal strength to atmospheric strength.

45. Transatlantic Radio Reception. C. A. Culver (U.S. Signal Corps). (*Journal of the Franklin Institute*, 187, pp. 529—579, 1919.)

This communication deals with the results of an investigation of the reliability of various receiving stations for transatlantic reception. Comparisons were made by the shunted telephone method using low horizontal aerials. Signal audibility was found proportional to the 1·2 power of the length of the horizontal aerial. Signal strength at different receiving stations was found to vary as between one station and another at the same time of day. The signals at a given station might show a comparatively satisfactory signal audibility for a short period of time, while at the same time signals from another transmitting station were below normal strength. Various devices for eliminating atmospheric interference were also tested but with negative results.

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The experiments indicated that the strength of X's of local origin varied inversely with the velocity of the wind and the air temperature. A marked agreement was found between X-strength and the humidity of the air, while variations in the X-strength corresponded directly with changes in the value of the horizontal component, H, of the earth's magnetic field.

46. ELECTROMAGNETIC WAVES. T. J. I'a. Bromwich, D.Sc., F.R.S. (*Philosophical Magazine*, 38, p. 143, July, 1919.)
A mathematical paper devoted entirely to the development of electromagnetic theory.

47. TRANSMISSION OF ELECTRIC WAVES ROUND THE EARTH. G. N. Watson, D.Sc. (*Proceedings of the Royal Society*, 95A, pp. 546—563, July, 1919.)
A mathematical paper devoted to radio transmission theory. It investigates the consequences of the assumption that the earth is surrounded by a concentric conducting layer (Heaviside layer) at a considerable height, and of the ionisation theory of wave refraction and reflection. The conclusion shows that the ionisation theory is sufficient to explain the observed facts concerning the rate of decay of electric waves transmitted over large sheets of water, and confirms the theory put forward by Heaviside and Eccles. See also RADIO REVIEW, p. 78.

48. PROPAGATION OF ELECTROMAGNETIC WAVES ROUND THE EARTH. Balth. van der Pol. (*Philosophical Magazine*, 38, p. 365, September, 1919.)
A mathematical paper devoted to the theory of wave transmission round the earth. It deals with the theoretical solution of the problem of defraction round a sphere of electric waves emitted from a source close to the sphere, and of wave lengths small in comparison to the circumference. It is suggested that the daytime signal strengths should be considered as normal instead of the night-time ones. The object of this article is the comparison of the observed normal value with the magnitude to be expected according to the defraction theory. Numerical data are given by which it is shown that the actual value of the received wave amplitude according to Austin's measurements is about two million times larger than the value to be expected by the pure defraction theory. The cause for this discrepancy must be looked for higher up in the atmosphere. Eccles' theory of ionic defraction is therefore strongly supported by these conclusions. See also RADIO REVIEW, p. 78.

49. THE SCIENTIFIC PROBLEMS OF ELECTRIC WAVE TELEGRAPHY. J. A. Fleming, D.Sc. (*Journal of the Royal Society of Arts*, 67, pp. 597—605, 612—618, 625—631, August, 1919.)
These Cantor lectures give a general summary of radio transmission and reception methods.

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50. A New Type of Receiving Tuner. M. B. Sleeper. (*Everyday Engineering Magazine*, 7, p. 292—295, August, 1919.)

An article dealing with the uses of the "honeycomb" standard inductances manufactured by the de Forest Radio Co. (U.S.A.). These are multi-layer coils wound with spaced turns to reduce the self-capacity and high-frequency resistance. Wave-length curves are given for these coils used in combination with various capacities.

51. Telephone Relays for Wireless. L. N. Brillouin and G. A. Beauvais. (*British Patents* 127013, 127014, March and November, 1916.)

This patent relates to multi-valve receiving amplifiers, in which the grid is worked at a positive potential with respect to the filament.

Less interference from strong signals and X's is claimed.

52. An American Receiver used on French Ships. (*Everyday Engineering Magazine*, 7, pp. 296—298, August, 1919.)

A general illustrated description is given of valve receiving sets used on certain French vessels. A single "French" detecting valve is employed.

53. Wireless Signalling Systems. I. Shoenberg and Marconi's Wireless Telegraph Co., Ltd. (*British Patent* 127634, May, 1917.)

Relates to the use of A.C. for the heating of valve filaments.

54. The Problems of Vacuum Tube Circuits. L. M. Clement. (*Everyday Engineering Magazine*, 7, pp. 300—302, August, 1919.)

A consideration is given of the amplification obtainable with various arrangements of amplifying valves, using resistance, inductance, or inductive couplings.

55. Improvements in Vacuum Tubes. H. W. Edmundson and W. T. Munro. (*British Patent* 127724, June, 1918.)

Describes a metallic screen round the anode of a valve to prevent heating of the glass stem and deposition of a conducting film on leading-in seals.

56. Cascade Amplification of a Single Vacuum Tube. (*Wireless Age*, 6, p. 23, July, 1919.)

This article describes a valve developed by Alexander Nicholson. The filament surrounds the first control electrode, and a cylindrical plate or anode encloses the whole. Two other grids and anodes are mounted on the outside of the above construction. By this means a three-stage amplification may be obtained in a single tube.

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57. THE APPLICATION OF AMPLIFIERS TO THE RECORDING OF WIRELESS SIGNALS. H. Abraham and E. Bloch. (*Comptes Rendus*, 169, pp. 282—285, August, 1919. *Revue Générale de l'Electricité*, 6, pp. 323—324, September, 1919.)

A frame aerial receiver is used in combination with two multi-valve amplifiers, of eight and three valves respectively. The first five valves are used for radio frequency amplification, the sixth as a detector, and the last two for low frequency amplification. To the end of this amplifier a special three-stage amplifier is connected, arranged with the grid of the last valve maintained normally at a negative potential, so that the plate circuit current is practically zero. The reception of the signal causes the plate current to jump to the saturation value, and so influences the recorder. This second amplifier thus takes the place of the usual relay.

Any ordinary Morse printer or recording galvanometer may be used. Medium strength atmospherics do not affect the recorder. Using a frame coil of forty turns 1·2 metres diameter, successful records of transatlantic signals have been obtained. | |

58. A COMPARISON OF THE WAVE FORM OF THE TELEPHONE CURRENT PRODUCED BY A THERMAL DETECTOR AND BY A RECTIFIER IN HETERODYNE RECEPTION. Balth. van der Pol, D.Sc. (*Proceedings of the Physical Society of London*, 31, pp. 290—298, August, 1919.)

A theoretical treatment is given of the wave form of the telephone current resulting from the heterodyne method of reception of wireless signals.

When a detector is used generating a potential difference at the telephone terminals proportional to the square of the aerial current, it is shown that the lowest frequency "harmonic" of the resultant current is

$$I_1 I_2 \cos(\omega_1 - \omega_2)\, t.$$

With a rectifying detector the theory becomes more involved, and the telephone current is $I_1 \cos \omega_1 t - I_2 \cos \omega_2 t$, with the condition that when this function is negative it is replaced by zero. The fundamental frequency of this function is $\frac{1}{2\pi}$ times the greatest common factor, f, (including fractions) of $(\omega_1 + \omega_2)$ and $(\omega_1 - \omega_2)$, so that $\omega_1 + \omega_2 = (p+q)f$ and $\omega_1 - \omega_2 = (p-q)f$ where $(p+q)$ and $(p-q)$ are the smallest integers, allowing $(\omega_1 + \omega_2)$ and $(\omega_1 - \omega_2)$ to be expressed in this form.

The relative magnitudes of the amplitudes of the different harmonics are wholly determined by the values of p and q. The harmonics of the order

$$(p+q),\ 2(p+q),\ 3(p+q),\quad .\quad .\quad .\ \text{etc.}$$

and

$$(p-q),\ 2(p-q),\ 3(p-q),\quad .\quad .\quad .\ \text{etc.}$$

will have much greater amplitudes than the remaining harmonics.

It is further shown that the amplitude of the harmonic of order $(p-q)$ is, for practical cases, much larger than that of the fundamental, and that

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it is likely that the ear will take the harmonic of order $(p - q)$ as determining the pitch of the sound in the telephone receiver, as in the case of the thermal detector. Owing to the larger number of harmonics obtained with the rectifier, the thermal detector shows a theoretical advantage, from the point of view of interference from other wave lengths.

59. Improvements in Receivers for Wireless Signals. C. S. Franklin and Marconi's Wireless Telegraph Company. (*British Patent* 128673, September, 1917. Patent accepted July 3rd, 1919.)

The use of the heterodyne method of reception for very high frequencies presents difficulties through inability to maintain the required frequency difference between the local and the incoming oscillations. The arrangement described in this specification provides for the regular variation of the local frequency so that the heterodyne beat frequency passes through the whole range of periods up to about 150,000 per second, a considerable number of times per second. The local variation of frequency may be obtained by a small rotary condenser connected in parallel with the oscillation circuit. The frequency of the capacity variations of this condenser may be arranged to give a musical note, such as, for example, 1,000 variations per second. Alternatively, a rapid variation of the inductance of the circuit may be made to produce a similar effect.

60. Improvements relating to Wireless Signalling Systems. The General Electric Company (U.S.A.). (*British Patent* 129722, December, 1917. Patent accepted July 24th, 1919.)

The receiving conductor or "aerial" is formed as a frame coil which is placed in the vertical plane containing the receiving station and the desired transmitting station. The second coil is mounted perpendicularly to the main receiving coil, with the object of screening the receiving coil from the undesired waves emitted from an adjacent transmitting station. The main receiving circuit should be tuned to the wave length of the station from which the signals are to be received, while the second coil at right angles is tuned to the frequency of the interfering station which is to be cut out.

61. Improvements in Apparatus for Eliminating Interference. H. Richmond and Marconi's Wireless Telegraph Company. (*British Patent* 130107, April, 1918. Patent accepted July 25th, 1919.)

The wireless receiving apparatus adapted to prevent interference by signals from undesired stations comprises a pair of directive frame aerials mounted perpendicularly to one another. The plane of one of the aerials is arranged to include the station from which it is desired to receive signals. The energy received on this aerial is transferred to the receiving circuit and detector in the usual manner. The same receiving circuit is also coupled

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adjustably to the second frame aerial. Signals from an undesired station affect both aerials and by adjusting the couplings the undesired signals may be neutralised in the receiving circuit.

62. IMPROVEMENTS IN WIRELESS RECEIVING APPARATUS. R. A. Weagant, F. N. Waterman, and Marconi's Wireless Telegraph Company of America. (*British Patent* 129625, Convention date July, 1918. Application date for British Patent, May, 1919.)

The aerial arrangements dealt with in this Patent are described in RADIO REVIEW Abstract No. 18.

63. THERMIONIC DEVICES FOR MAGNIFICATION PURPOSES. G. M. Wright and Marconi's Wireless Telegraph Co., Ltd. (*British Patent* 127651, May, 1917.)

This patent deals with the use of a succession of valves so arranged that the strength of atmospheric disturbances is reduced, while, at the same time, any desired magnification can be obtained. The circuit for two valves is shown in Fig. 5.

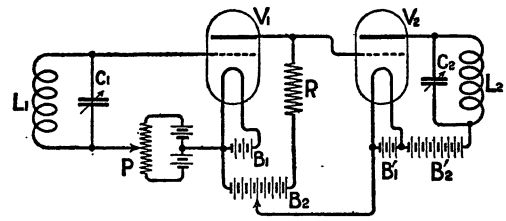

FIG. 5.

64. DUPLEX WIRELESS SIGNALLING. General Electric Company (U.S.A.). (*British Patent* 127335, April, 1917.)

An arrangement for duplex wireless signalling employing separate transmitting and receiving aerials at each station. The effect of the emitted waves on the adjacent receiving aerial is neutralised by impressing opposite potential variations on the receiving aerial by coupling it electrostatically or electromagnetically to the transmitting aerial. Different frequencies may be used for transmitting and receiving.

65. WIRELESS AERIALS FOR AIRCRAFT. B. Binyon. (*British Patent* 127434, June, 1918.)

An easily detachable trailing aerial for aircraft is described. The aerial wire is contained inside the plummet which is dropped from the 'plane.

66. THE CABOT CONVERTER. C. F. Caines. (*Proceedings Inst. of Radio Engineers*, 7, p. 281, June, 1919.)

A description of the Cabot commutator converter for supplying high-tension direct current from a polyphase A.C. source. The theory of the commutation is given and specifications for a 1 k.w. transformer for use with this apparatus. Voltages up to 100,000 D.C. may be obtained.

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67. Wireless Control of Torpedoes. A. E. Ericson. (*British Patent* 128295, July, 1917.)

Synchronously revolving commutators are used at the transmitter and receiver in order to determine the use to which any given impulse is put in controlling the torpedo.

68. Wireless Control of Distant Apparatus. H. J. G. Proumen and A. le C. de Lautreppe. (*British Patent* 127848, May, 1917.)

69. Radio Signalling. J. Stone-Stone. (*Proceedings of the American Institute of Electrical Engineers*, 38, p. 933, July, 1919.)

The Annual Technical Committee report, giving a brief summary of the year's radio progress.

70. Radiotelegraphy in Competition with Wire Telegraphy. R. B. Black. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 391—407, August, 1919. *Telegraph and Telephone Age*, pp. 434 and 459—462, September, 1919.)

This paper deals with some of the obstacles encountered in overland radio service. The organisation and operation of the Pacific coast chain of duplex radio stations belonging to the Federal Telegraph Company is described in detail.

71. Radiotelegraphy by Infra-Red Rays. J. Herbert-Stevens and A. Larigaldie. (*Comptes Rendus*, 169, pp. 136—137, July, 1919. *Revue Générale de El'lectricité*, 6, pp. 476—477.)

The results obtained in recent wartime experiments in infra-red photo-telegraphy are described. A thermo-electric detector was used, with an arc or incandescent lamp for transmitter. Ranges up to twelve miles have been obtained.

Correspondence.

HARDENING AND SOFTENING OF IONIC TUBES.

To the Editor, the "Radio Review."

Sir,

The phenomena described by Professor C. L. Fortescue on page 35 of your October issue occur in all kinds of ionic tubes, and are of immediate importance to those who use the thermionic high-vacuum valve with either two or three electrodes. Dr. Bryan's explanation is given on the same page. I now write to offer another explanation.

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Suppose the filament to be at its normal temperature in an ordinary commercial tube and suppose that the voltage applied is producing about half the saturation current. Doubtless some of the molecules present will be ionised by collision with the electrons, but in a steady state of affairs the electron flow will be sufficient to prevent the positive ions reaching the cathode in any considerable number. Now let an unusually high voltage be applied between the anode and filament without alteration of the temperature of the latter so that the saturation current is being taken. Then more positive ions will be formed because the collisions will be more vigorous, their speed will be greater, and there will be appreciable bombardment of the filament by positive ions. We may suppose that these ions become embedded in the filament to form what is called occluded gas.

Now suppose that the voltage applied between the anode and filament is reduced to an unusually low value so that the electron current is far below saturation. The space charge accumulates densely near the filament and the voltage gradient at the surface of the filament becomes negative. This is indicated by the curve marked *V* in Figure 3 on page 15, of my paper in your October issue. Hence the positive ions lying upon, or embedded in the filament tend to be drawn into the space charge. This is evident because the same space charge that pushes negative ions (electrons) back into the filament will encourage positive ions to leave it. And these positive ions if they enter the space charge in quantity lead to the flow of a greater current through the vacuum and make the valve, as we say, "soft."

In this explanation the assumption is made that the positive ~~electrons~~ ions occluded by the filament remain there unneutralised. This assumption seems reasonable when one recalls that according to the kinetic theory of matter the averaged velocity of, say, the hydrogen molecule in the incandescent filament is much greater than that of the metal molecule and is only fifty times smaller than the averaged velocity of the electrons in the metal. Even if the filament is allowed to cool and is then reheated the occluded gas may be expected to become ionised *in situ*. Hence the superior conductivity of gas liberated from a high temperature cathode over cold gas admitted into a tube.

This method of hardening has been used for several years in the manufacture of valves, each tube being treated individually. It seems worth mentioning that it should be possible to utilise these phenomena in the construction of what might be called an electric pump for the production of the highest vacuum. The pump would consist of a cathode of very large surface and an anode in a glass bulb with a side tube to which the vessels to be exhausted to the limit would be sealed. A high voltage between the anode and the cathode in the pump would ionise and deposit the gas coming from the vessel to be evacuated.

Yours faithfully,
W. H. ECCLES.

City and Guilds Technical College,
Finsbury, E.C. 2.
October 20th, 1919.

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THE
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THE
RADIO REVIEW

VOL. I DECEMBER, 1919 NO. 3

The Elimination of Magneto Disturbance in the Reception of Wireless Signals on Aircraft.*

By CAPT. JAMES ROBINSON, R.A.F., M.Sc., Ph.D.

ON aircraft, and more especially on aeroplanes, the problem of the reception of wireless signals is complicated by two factors :—

(1) The external noise due to the engines and the rush of wind, and

(2) The disturbance produced in the receiver due to the magneto of the engines.

To deal with the external noises, the only possible thing is to use helmets and earpieces which fit as closely as possible to the head and ear. It is possible by taking such precautions to cut down the noise of the engines very appreciably. In any case, there is always so much noise that signals must be of much greater intensity than at ground stations in order to be of any use. It is thus essential to use the best of amplifiers in aeroplanes.

To deal with magneto disturbance a very different procedure is required, as the disturbance is electromagnetic, produced by the spark discharge of the magneto. Unless this disturbance is cut out, no gain is obtained by increasing the amplification of signals, for the amplifier usually also increases the magneto disturbance in the same proportion as it increases the strength of signals. This disturbance is especially bad in directional work, because the wireless energy picked up by loops is small.

* Paper received August, 1919.

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Some laboratory experiments were undertaken to find out the cause of this magneto disturbance and to try to find effective methods for cutting it out. A magneto with six sparking plugs was fitted on a bench in the laboratory, the magneto being driven by a belt from shafting. A D.F.* single coil with a valve amplifier was used for reception, the amplifier having high and low frequency parts.

The effect of distance was first investigated. Moving the D.F. coil and amplifier together, it was found that the disturbance is large when within eight to ten feet of the magneto system and diminishes rapidly as the distance is increased above this.

The D.F. coil and amplifier were then moved separately, long leads being employed between them. It was found that with the D.F. coil near the magneto and the amplifier far away, the disturbance was just as bad as in the converse case of the amplifier near the magneto. However, when the D.F. coil was near the magneto, it was discovered that the disturbance was not cut down by breaking the circuit to the amplifier. One lead was broken at the coil end and then the other, and the disturbance was still bad. Hence it appeared that the leads were of importance. When the leads were taken away from the neighbourhood of the magneto, the disturbance diminished.

The leads were then removed from the amplifier altogether, and it was found that the disturbance vanished, unless of course the amplifier was close to the magneto. If the amplifier was used alone and was at such a distance from the magneto that there was no disturbance it was found that the disturbance appeared if a lead was stretched between the magneto and amplifier without touching either of them and in fact being at a distance of a foot from both the magneto and the amplifier. This showed that the leads were responsible to a large extent for producing the disturbance.

Attempts were made to shield the leads by putting them in an earthed tube, and this again inside another earthed tube, but without effect.

However, these experiments led to the inference that the cause of the disturbance was probably the emission of very short waves by the magneto system. This inference was strengthened by the following simple experiments. With the amplifier disconnected from the D.F. system and at a distance such that no disturbance

* D.F. = "Direction Finding."

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was observed, the disturbance appeared when a wire of a few inches length was joined to one terminal of the amplifier the free end of this short wire being insulated. This seemed to show that this short wire acted as an aerial for very short waves. The short wire now had its free end joined to the other terminal of the amplifier. It was found that the amount of the disturbance depended on the shape given to this wire. When the wire was bent into a shape nearly circular, the disturbance was larger than when it was drawn out into an elongated form. This seemed to put beyond doubt the inference that the disturbance was due to short waves, for giving various shapes to this short wire was equivalent to giving different frequencies to this short wave aerial circuit.

In order to verify this conclusion finally, a short wave stopper was made, consisting of a variable condenser of a few centimetres capacity and of a very small inductance consisting of two or three turns of wire on a former of about two inches diameter. The D.F. coil was now joined up to the amplifier and placed in a position where magneto disturbance was obtained. The small

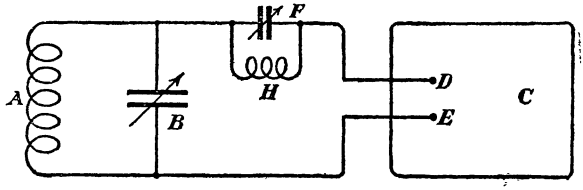

FIG. 1.

A. D.F. Coil.
B. Tuning condenser.
C. Amplifier.
D. Grid terminal of amplifier.
E. Filament terminal of amplifier.
F. Small variable condenser.
H. Small inductance.

condenser F and the small inductance H were joined up to form an oscillating circuit with a frequency corresponding to wave lengths which could be varied from two to ten metres. This oscillating circuit was placed in the lead from the coils to the amplifier close up to the grid terminal of the amplifier, and it is known that such a tuned circuit offers very large resistance to waves of the same frequency. It was found by this circuit that it was possible to cut down the magneto disturbance very considerably by varying the condenser F, thus proving that a large part, if not all of the disturbance, is due to waves of wave length between two and ten metres.

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It is easy to see how such waves are produced. The magneto system consists of means for producing a high potential and a spark gap for discharging it. Leads are necessary to connect the magneto to the spark gaps and these leads have small capacity and small inductance, thus acting as oscillators and radiators of short wave lengths. The spark gaps have leads of various length so that various short waves are radiated from the magneto system of an aeroplane.

To get efficient cutting out of the disturbance by this means, it would be necessary to have a number of tuned stoppers. It was however suggested that all wave lengths would be cut out by using an inductance which would act as a choke for short waves. An inductance of 1,000 to 2,000 microhenries was found to be very efficient and to be without appreciable effect on received signals. Such a choke has increased the range of reception on aeroplanes very considerably.

However on certain aeroplanes, especially of large type, these short wave stoppers are not efficient enough for D.F. work. This is probably because the radiated waves from the magneto system of such aeroplanes are longer than those obtained in the laboratory experiments. It is easy to understand this for there are sometimes very long leads connected with the magneto system.

Various other devices were tried in the laboratory to try to cut out the disturbance completely. Stoppers for very long waves were tried without the smallest success.

It was thought that possibly a D.F. coil with a large number of turns might not be increased in efficiency by increasing the number of turns indefinitely. A device was tried of shorting a number of turns at each end of the frame. It was considered that these shorted turns might absorb all the magneto disturbance, but it was found to be of no benefit.

Balancing methods were tried on the assumption that it ought to be possible to pick up extra disturbances from the magneto of equal magnitude and opposite phase by the use of a search coil. Search coils were tried in the high-frequency circuit of the D.F. coil, and again in the low-frequency circuit of the telephones, in various forms. Some slight amount of cutting down of the disturbance was obtained by some of these balancing methods, but they were abandoned as being too complicated.

The most efficient magneto cutting-out device is to shield the magneto system completely. The magnetos themselves should

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be encased in metal shields. The high-tension leads from the magneto to the sparking plugs should be run in earthed tubes. The same applies to the low-tension leads. When this is done properly there is no trace of magneto disturbance in the most sensitive receiving system. It is not always necessary to put the magnetos in special metal cases. This applies in the cases where the engines are completely cowled. The earthing of the metal shields of the high-tension and low-tension systems is most important. It is not sufficient to bind earthing wires round the metal shield and the earth system if these metal parts are covered in grease. Good earths should be made to the common potential of the metal framework of the aeroplane, consisting of the engines, tanks, and bracing wires. The metal casing of the H.T. leads must be earthed every 18 inches or 24 inches by as short leads as possible. This applies also to the low-tension leads. This earthing at various places provides closed circuits which form oscillating circuits for very high frequencies, and thus help to absorb the short waves radiated from the magneto system.

This shielding of the magneto system is invariably efficient if care is taken. It is purely a matter of paying attention to detail, and in a large number of cases it has always been successful. At times the disturbance appears so bad as to make it seem hopeless to try to cut it down. Stray leads going past exposed magneto parts and then past the receivers are responsible for conveying the magneto disturbance.

In this connection, it is worth noting that disturbances appear which are often called magneto disturbance, but which are really nothing of the sort. There is so much vibration on aeroplanes that if there is anything loose about the receiver or the D.F. system, a vibration is set up which produces noises similar in character to magneto disturbance. Such cases have arisen as the following :—

(1) Loose connection in the receiver.
(2) Loose connection inside a valve.

An effect has been observed in certain types of amplifier which has so far not received satisfactory explanation. It is possible to choose valves and conditions such that without any other aid, the magneto disturbances are entirely cut out. This is of such importance that with such amplifiers it is worth while spending some time in interchanging valves and trying various adjustments.

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When the correct conditions are obtained, it is found that as the filament current of the amplifier is increased, the signals increase continuously in strength but the magneto disturbance increases to a point and then suddenly vanishes only to reappear if the filament current further increases (Fig. 2).

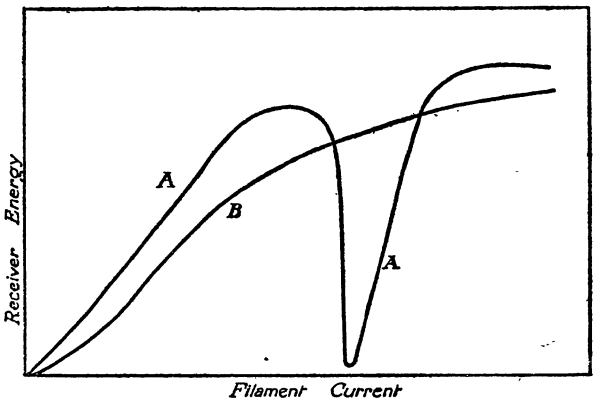

FIG. 2.

A. Magneto energy. B. Signal energy.

It is hoped that this effect will soon be understood so that it can be reproduced at will.

My thanks are due to Major J. Erskine Murray, D.Sc., for his interest and advice in the course of these experiments.

On the Goniometric Functions Applicable to Directive Aerials.

By A. BLONDEL.

(*Continued from page* 66.)

THE resultant electromotive force for the case of a Type D loop will be the integral of the elementary electromotive forces $2e_0 \sin\phi$ as defined above, calculated for each element of height dz.

In short the simple goniometric functions $\sin\phi$ and $\cos\phi$ previously used are replaced by more complicated integral functions:

$$\left.\begin{aligned} \text{gon}\,\theta_D &= \int_{z_0}^{z_1} \sin\left[\frac{2\pi f(z)\,\sin\theta}{\lambda}\right] dz \\ \text{gon}\,\theta_S &= \int_{z_0}^{z_1} \cos\left[\frac{2\pi f(z)\,\sin\theta}{\lambda}\right] dz \end{aligned}\right\} \quad . \quad . \quad . \quad (23)$$

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In the case where the antennæ are simply sloping straight wires for which the distance from the centre of the loop is x at the base of the aerial and x_1 at the top, and putting $z_0 = 0$ at the base, the function $f(z)$ has the simple form

$$x = x_0 + \frac{x_1 - x_0}{z_1} z.$$

If the aerial has a polygonal shape, each rectilinear section has an equation of the same form.

Generally it will be seen that the expression gon θ, instead of having the simple value given above, takes the form of the ratio of two integrals

$$\frac{\text{gon } \theta}{\text{gon } \left(\frac{\pi}{2} - \theta\right)} = \frac{\int_{z_0}^{z_1} \sin \left[\frac{2\pi f(z) \sin \theta}{\lambda}\right] dz}{\int_{z_0}^{z_1} \sin \left[\frac{2\pi f(z) \cos \theta}{\lambda}\right] dz} \quad . \quad . \quad . \quad . \quad (24)$$

For each value of θ, these integrals may be calculated, in any case by means of graphical integration by plotting the curve of the sines as a function of z.

It is possible therefore for any value of θ to determine the value of the function gon θ and to draw up a double-entry table or else a standardising curve, similar to those described in the above simpler case, from which θ can be determined by the general formula as soon as $\frac{\psi + \psi'}{2}$ has been measured by the radio-goniometer.

The accuracy observed in calculating gon θ must increase as the wave length decreases. The same must apply to the precision with which the aerials are constructed, so that for small wave lengths of 100 to 150 metres it is advisable that the aerials be constructed each of a single wire, rather than of a number of wires more or less separated from each other.

We see that the use of short wave lengths as prescribed by the International Convention introduces certain complications which do not exist with larger wave lengths.

S type frames may be connected to a fixed earth wire at an equal distance from the two aerials, so that the vectorial electromotive force of this earth wire is simply proportional to e_0 and is in phase

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with the resultant electromotive force of the two aerials, so that its effect is added in the circuit acting on the detector (represented by mutual inductance L).

The two equations (17) are therefore replaced by two others, of the following form:

$$\left.\begin{aligned} L + M\,\mathrm{gon}\,\theta - N\,\mathrm{gon}\left(\frac{\pi}{2} - \theta\right) &= \frac{H(\epsilon')}{2e_0} \\ L + N'\,\mathrm{gon}\left(\frac{\pi}{2} - \theta\right) - M'\,\mathrm{gon}\,\theta &= \frac{H(\epsilon')}{2e_0} \end{aligned}\right\} \quad . \quad . \quad . \quad (25)$$

The second term may be eliminated by subtracting these two equations term by term. It will then be seen that the term L is eliminated so that the solution is the same as for equations (17). This implies, of course, that the two earth wires are arranged in an exactly identical manner, and run from the same point in each loop, a condition which can easily be realised. It should be noticed also that L is eliminated in the case of the simple loops.

On the other hand, in the alternate measurement method (equation 19) the term $2e_0L$ must be added to each bracket under the sign F except when the function F is simply one of direct proportionality. When this is not the case the earth wire introduces a fresh complication into the comparison method.

II. THE EFFECT OF WAVE DECREMENT.

The logarithmic decrement does not give rise to any appreciable disturbance when using a single loop "zero-method" arrangement, since the two positions where the sound in the telephones disappears are always symmetrical with respect to the direction of the waves.

On the contrary in the case of direction-finding systems using two frame aerials, when the direction of the waves approximates to the plane of one of the loops, the magnitude and phase of the two induced currents may become unequally modified, and it is no longer correct to compare them in the same manner as in the case of undamped waves. The conditions under which the comparison methods may be legitimately applied must therefore be examined and the errors estimated.

Two types of wave damping must be considered :—

(*a*) Waves of simple decrement, produced by the sudden excitation of the sending aerial which is then left to

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oscillate freely (neglecting the transient period at the moment of shock excitation).

(*b*) Waves of complex decrement which occur (1) in the case of a quenched spark transmitter; and (2) in the ordinary waves resulting from the coupling of the aerial with a local oscillating circuit. In this latter case there is an alternating exchange of energy between the aerial and the oscillating circuit, the state of affairs in the aerial being represented algebraically by the sum of two oscillations of unequal wave length, of more or less unequal damping and for each of which a starting period should be considered.

(*a*) WAVES OF SIMPLE DECREMENT.

Neglecting the transients at the commencement of the oscillations, the received waves have simple decrement and constant frequency. The effect of damping is two-fold; firstly it modifies the time period, but this makes no radical change and it is merely necessary to substitute the new frequency; secondly, it weakens the wave as it is propagated, thus giving rise to a difference between the amplitudes of the electromotive forces induced in the two aerials, which increases with their distance apart. An important modification of the goniometrical functions results therefrom.

Goniometrical Functions.—For simplicity, let $\omega = 2\pi/T$, where T = the time period; $\delta = \Delta/T$, be the damping coefficient, Δ being the logarithmic decrement *; $\pm t'$ be the time representing the phase difference between each antenna (assumed to be vertical) and the axis mentioned above; $2\pi\xi$ be the corresponding phase angle $[\xi = t'/T = x \sin \theta/\lambda]$; $j = \sqrt{-1}$. The other symbols are the same as used in Section I. above. The expression for the electromotive force, e_0, induced in a simple antenna placed on the vertical medial axis of the loop, takes the form:

$$e_0 = E\epsilon^{(-\delta + j\omega)t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

Since the phase of the waves reaching antenna 2, nearest to the transmitting station, is $-t'$ in advance, while, when they reach

* The damping, as is well known, may be very small (0·05 to 0·01) with transmitters of long wave lengths using umbrella aerials, or aerials with low radiating power; it becomes very important (0·2 to 0·5) with simple aerials with large radiating power, excited either directly or indirectly. The latter are imperative with short waves to obtain the necessary range.

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antenna 1, furthest from the transmitter, the phase lag is $+ t'$, the expressions for the electromotive forces e_1 and e_2 become :

$$e_1 = e_0\epsilon^{+(\delta + j\omega)t'} = e_0\epsilon^{+(\Delta + 2\pi j)\xi}$$

$$e_2 = e_0\epsilon^{-(\delta + j\omega)t'} = e_0\epsilon^{-(\Delta + 2\pi j)\xi}$$

By addition and subtraction, we obtain respectively :

(Type D) :

$$e_1 - e_2 = 2e_0 \sinh (\Delta + 2\pi j)\,\xi$$

$$= 2e_0 (\sinh \Delta\xi \cos 2\pi\xi + j \cosh \Delta\xi \sin 2\pi\xi) \quad . \quad (27)$$

(Type S) :

$$e_1 + e_2 = 2e_0 \cosh (\Delta + 2\pi j)\xi$$

$$= 2e_0 (\cosh \Delta\xi \cos 2\pi\xi + j \sinh \Delta\xi \sin 2\pi\xi) \quad . \quad (28)$$

The real part of these expressions represents the component in phase with the electromotive force e_0 in the imaginary aerial, and the imaginary part, the component at right angles. The amplitudes of the resultant vectors are respectively $2e_0G_D$ and $2e_0G_S'$, writing G_D and G_S' for the radiogoniometric functions :

(Type D) :

$$G_D = \sqrt{(\sinh \Delta\xi \cos 2\pi\xi)^2 + (\cosh \Delta\xi \sin 2\pi\xi)^2}$$

$$= \sqrt{\sinh^2 \Delta\xi + \sin^2 2\pi\xi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

(Type S) :

$$G_S' = \sqrt{(\cosh \Delta\xi \cos 2\pi\xi)^2 + (\sinh \Delta\xi \sin 2\pi\xi)^2}$$

$$= \sqrt{\sinh^2 \Delta\xi + \cos^2 2\pi\xi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30)$$

The corresponding phase angles are respectively :

$$\tan \gamma_D = \frac{\tan 2\pi\xi}{\tanh \Delta\xi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

$$\tan \gamma_S = \tan 2\pi\xi \,.\, \tanh \Delta\xi \quad . \quad . \quad . \quad . \quad (32)$$

The goniometrical functions obtained by dividing (27) and (28) by $2e_0$ are no longer scalar functions but are vectorial, since there is a phase difference between them caused entirely by the damping.

It is easy to explain this more clearly by a geometrical interpretation. On page 58 the electromotive forces in the two aerials were represented simply by two equal vectors E_1 and E_2 making angles $+ \phi$ and $- \phi$ respectively with the axis of reference corresponding to the phase of the central imaginary aerial. The damping does not change the values of the angles ϕ, but alters the values of the vectors E_1 and E_2 by multiplying them by the exponential

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$\epsilon^{-\delta t}$, δ being the damping coefficient defined above. As shown in Fig. 10, the extremities a_1 and a_2 of these vectors (having origin at the fixed point O) no longer trace out a circle as ϕ varies, but a logarithmic spiral.

Set off $a_2\, a_3 = Oa_1$, and join Oa_3 and $a_1\, a_2$, then the vector Oa_3 which is the resultant of $E_1 + E_2$, represents what we have called G_S' above, and makes an angle of lead γ_S with the line OX (angles of lag are measured in the direction of the arrow).

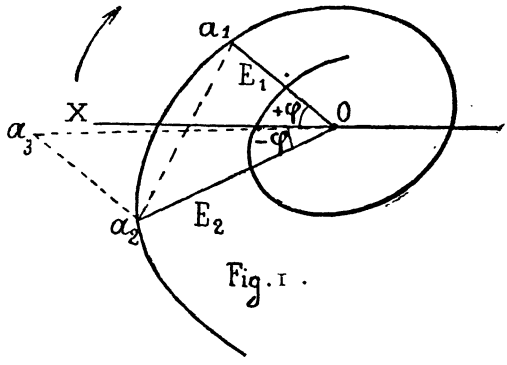

Fig. 1.

In the same way, the vector $a_2\, a_1$ representing the geometric difference of E_1 and E_2 corresponds in magnitude and phase with G_D, and the angle between $a_2\, a_1$ and OX is what we have called γ_D above.

By the help of Fig. 10 we can easily obtain expressions for these vectors and angles, by making use of the projections of E_1 and E_2 upon OX and upon an axis perpendicular to OX, thus:

Projection of $a_2\, a_1$ on $OX = e_0(\epsilon^{\delta t'} - \epsilon^{-\delta t'})\cos\phi$
$= 2e_0 \sinh \delta t' \,.\, \cos\phi.$

Projection of $a_2\, a_1$ on perpendicular to $OX = e_0(\epsilon^{\delta t'} + \epsilon^{-\delta t'})\sin\phi$
$= 2e_0 \cosh \delta t' \,.\, \sin\phi.$

Projection of Oa_3 on $OX = e_0(\epsilon^{\delta t'} + \epsilon^{-\delta t'})\cos\phi$
$= 2e_0 \cosh \delta t' \,.\, \cos\phi$

Projection of Oa_3 on perpendicular to $OX = e_0(\epsilon^{\delta t'} - \epsilon^{-\delta t'})\,.\,\sin\phi$
$= 2e_0 \sinh \delta t' \,.\, \sin\phi$

which may be easily transformed by replacing $\delta t'$ by its value $\Delta\phi/2\pi = \Delta\xi$. In this manner the expressions (29), (30), (31), and (32) may easily be obtained.

In discussing the phase of the differential resultant $e_1 - e_2$, it is easier to consider the complementary angle $\psi = \frac{\pi}{2} - \gamma_D$, which may be calculated by the expression

$$\tan\psi = \frac{\tanh \Delta\xi}{\tan 2\pi\xi}.$$

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As a matter of fact ψ becomes zero with undamped waves, and differs little from it with damped waves (Fig. 11).

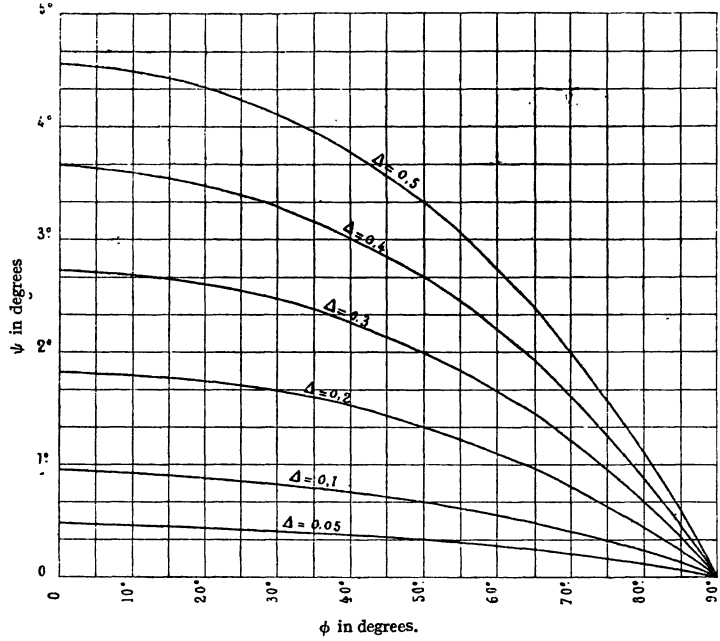

FIG. 11.

In the more general case of slanting aerials, it is necessary, as we have seen above, to integrate the components of the electromotive force at each point, making use of a knowledge of the equation of the shape of the loop, $\pm x = f(z)$—assuming for simplicity that the loop is symmetrical with respect to the vertical medial axis :

Type (D) :

$$\text{gon}\,\theta = \int_{z_0}^{z_1} \sinh \Delta\,\xi \,.\, \cos 2\pi\xi \,.\, dz + j \int_{z_0}^{z_1} \cosh \Delta\,\xi \,.\, \sin 2\pi\xi \,.\, dz \quad . \quad . \quad (33)$$

(Type S) :

$$\text{gon}\,\theta = \int_{z_0}^{z_1} \cosh \Delta\,\xi \,.\, \cos 2\pi\xi \,.\, dz + j \int_{z_0}^{z_1} \sinh \Delta\,\xi \,.\, \sin 2\pi\xi \,.\, dz \quad . \quad . \quad (34)$$

where $$\xi = \frac{f(z) \sin \theta}{\lambda}$$

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The calculation is therefore difficult.

Once in possession of the goniometrical functions for simple damped waves, it is easy to deal with the reception of these waves by frame aerial arrangements, using the same methods as employed above for undamped waves.

But the unknown function F representing the response of the detector with continuous waves, would here become considerably more complicated, if it were necessary to express it in greater detail, since it is known that the damping of the receiving circuits and their coupling, have a direct effect upon the strength of the damped current which passes through the detector.*

In any case—and this is the most important point to remember—because of the very fact that the waves are damped, the current to which they give rise is dissymmetrical and it is therefore no longer possible to neglect the direction in which the current commences with respect to the detector, when the latter is unsymmetrical, as is the case with crystal detectors.

If, for example, in the first instance the antenna a_1 receives the waves before the antenna a_2, and adjustments are made for the sound which is just audible in the telephones, the connections to the detector should be reversed in order to retain the same conditions when the loop is subsequently rotated so that antenna a_2 receives the waves before antenna a_1 in determining the second position of just audible sound. This complication can be avoided by the use of symmetrical detectors for integrating the energy. The effect of the wave damping can then be neglected as shown in Section III. below.

(*b*) WAVES WITH COMPLEX DECREMENT.

When the signals are formed of very highly damped wave trains, some account must be taken of the growth of each wave train. The calculation is therefore much more complicated even when it is assumed, as is done here, that both the loop (or system of two adjacent aerials) and the receiving circuit energised therefrom, are tuned sufficiently exactly to one of the two wave lengths set up by all indirectly coupled transmitters, that the effect of the other wave can be neglected.

It can merely be stated † that the electromotive force e_0 set up

* See, especially, M. Wien, *Annalen der Physik*, 8, p. 696, 1902; and Drude, *Annalen der Physik*, 13, p. 528, 1904.

† See, Bjerknes, *Wiedemann's Annalen*, 44, p. 74, 1891; 55, p. 121, 1895; M. Wien, *Jahrbuch der Drahtlosen Telegraphie*, 1, p. 462, 1908; Zenneck, "Handbook of Wireless Telegraphy," pp. 79—81, 1909.

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in the imaginary central aerial by the wave length utilised, is the difference between two imaginary exponentials representing the two different decrements Δ and Δ'. We may therefore write :—

$$e_0 = \eta E + \eta' E \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

where E is the maximum amplitude, $\eta = \epsilon^{(-\Delta + 2\pi j)\, t/T}$, and $\eta' = -\epsilon^{(-\Delta' + 2\pi j)\, t/T}$.

If, as above, $\pm\xi$ is the phase difference between the imaginary aerial and each of the two real antennæ, it is easily shown that the magnitude and phase of the resultant electromotive force in the loop is given by *

(Type D loops) :

$$e_1 - e_2 = 2E\eta \sinh (\Delta + 2\pi j)\, \xi + 2E\eta' \sinh (\Delta' + 2\pi j)\, \xi \quad . \quad (36)$$

(Type S loops) :

$$e_1 + e_2 = 2E\eta \cosh (\Delta + 2\pi j)\, \xi + 2E\eta' \cosh (\Delta' + 2\pi j)\, \xi \quad . \quad (37)$$

The response produced by the crystal detector being as stated above, a function F (depending upon the detector) of the electromotive force, of the [circuit] constants and of the dampings, it becomes necessary to separate out the terms involving Δ and Δ' and to consider the corresponding function F and F'. Each loop will therefore have a double goniometric function :—

(D loops) :

$$\left.\begin{aligned} \operatorname{gon} \theta &= \eta \sinh (\Delta + 2\pi j)\, \xi \\ \operatorname{gon}' \theta &= \eta' \sinh (\Delta' + 2\pi j)\, \xi \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (38)$$

(S loops) :

$$\left.\begin{aligned} \operatorname{gon} \theta &= \eta \cosh (\Delta + 2\pi j)\, \xi \\ \operatorname{gon}' \theta &= \eta' \cosh (\Delta' + 2\pi j)\, \xi \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (39)$$

and will give rise, at the detector, to a complex effect of the form

$$F\,(2E \bmod \operatorname{gon} \theta) + F'\,(2E \bmod \operatorname{gon}' \theta) \quad . \quad . \quad . \quad (40)$$

As an example, let us apply the preceding to the case of the compensation method with two loop aerials, of the same type and perpendicular to one another :

---

* If the aerials are not vertical, but have a shape expressed by the equation $\pm x = f(z)$ as a function of the height z, these expressions should be replaced by integrals of the form

$$\int_{z_0}^{z_1} 2E\eta \sinh (\Delta + 2\pi j)\, \frac{f(z) \sin \theta}{\lambda} \cdot dz + \int_{z_0}^{z_1} 2E\eta \sinh (\Delta' + 2\pi j)\, \frac{f(z) \sin \theta}{\lambda} \cdot dz,$$

for Type D loops, as an example. The calculation thus becomes complicated.

Further let us neglect the commencement of the building-up period of the oscillation in the loop by assuming that the wave reaches the two aerials at the instant when e_0 rises from zero—which is not quite correct, but the error is sufficiently small to entitle us to neglect it.

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As above, let M and N be the mutual inductances between these two loops and the detector circuit when the detector current is reduced to the minimum perceptible value; ϵ' the electromotive force corresponding to this minimum; M' and N' the values of M and N for the second position of the movable loop to give the same minimum. Equations (11) are then evidently replaced by the following:

$$F\,[2E \bmod (M \operatorname{gon} \theta - N \operatorname{gon} \alpha)] + F'\,[2E \bmod (M \operatorname{gon}' \theta - N \operatorname{gon}' \alpha)] = \epsilon' \quad . \quad . \quad (41)$$

$$F\,[2E \bmod (M' \operatorname{gon} \theta - N' \operatorname{gon} \alpha)] + F'\,[2E \bmod (M' \operatorname{gon}' \theta - N' \operatorname{gon}' \alpha)] = \epsilon' \quad . \quad . \quad (42)$$

writing $\alpha = \frac{\pi}{2} - \theta$ to simplify the expression, and noting that F and F' are positive. In the case of an energy integrating detector, the symbols F and F' indicate that the expressions within the brackets should be squared; but the calculation, although then possible, remains difficult. In the case of crystal detectors F and F' cannot be determined either theoretically or even empirically in any useful manner, since E is unknown when making an observation, and varies with the distance from the transmitting station. The elimination of F, F', and E is therefore no longer possible, and θ cannot be calculated by a geometrical relation as in the previous cases.

The problem is only capable of approximate solution in the particular case when the decrements Δ and Δ' are very small and the width of the loop, $2x$, is sufficiently small compared with λ to enable the differences between the magnitudes and phases of the electromotive forces e_1 and e_2 to be neglected. It is then correct to express e_1 and e_2 as in the case of sustained waves, the only condition being that the function F takes complete account of the form and of the two decrements of the waves received by the loops. This solution is moreover only applicable to the Type D arrangement.

The whole of the above demonstration shows that direction-finding by means of short waves and with receiving aerials having a spacing which is a considerable fraction of the wave length, introduces complications which become more serious as the wave-form of the oscillations constituting these waves becomes more complex. The approximations allowable for taking account of

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the decrement of the waves in a simplified manner are indicated below.

III. THE ERRORS DUE TO NEGLECTING THE DAMPING.

In practice it is only necessary to consider a single decrement, particularly with impulse type transmitters which are the only ones which can be recommended.

Returning to the case of a simple decrement ($\Delta' = 0$) the expressions for G_D and G_S' can be studied more easily by putting them in the form :

$$G_D = \sqrt{\sin^2\phi + \sinh^2\frac{\Delta\phi}{2\pi}} \quad . \quad . \quad . \quad . \quad . \quad (29a)$$

$$G_S' = \sqrt{\cos^2\phi + \sinh^2\frac{\Delta\phi}{2\pi}} \quad . \quad . \quad . \quad . \quad . \quad (30a)$$

This form is suitable for estimating the error introduced by neglecting the damping—*i.e.*, by taking the values of $\sin\phi$ and $\cos\phi$ for G_D and G_S' respectively.

This error, which is zero when $\phi = 0$, increases with ϕ. Since $\phi = \frac{2\pi x}{\lambda}\sin\theta$, the value of ϕ increases with θ (which has a range of 0 to $\pi/2$) ; ϕ reaches its maximum of $2\pi x/\lambda$ when $\theta = \pi/2$. This maximum increases when x/λ is increased. In practical cases x/λ is not greater than $1/4$, so that the maximum value of ϕ cannot exceed $\pi/2$. At this value the errors in G_D and G_S' will reach their greatest values. For the latter this error is $\sinh \Delta/4$, but for the former it is only $\sqrt{1 + \sinh^2(\Delta/4)} - 1$, *i.e.*, $\frac{1}{2}\sinh \Delta/4$ nearly. The effect of damping is therefore greater for G_S' than for G_D.

When $\sin\phi = \cos\phi$, that is when $\phi = 45°$ (corresponding to $\theta = \pi/2$, for $x/\lambda = 1/8$), the values of G_D and G_S' are equal, and the same error is made by taking them as both $= \sqrt{2}/2 = 0{\cdot}7$. Fig. 12 gives the values of G_D and G_S' as a function of θ; for the purposes of comparison, the corresponding values of G_D and G_S for $\Delta = 0$ (*i.e.*, for sustained waves) have also been plotted on the same diagram (dotted lines).

Even for the limiting case $x/\lambda = 1/4$ the error incurred by neglecting the damping hardly exceeds a few per cent., even for $\theta = \pi/2$. With a loop having a width of a quarter of a wave

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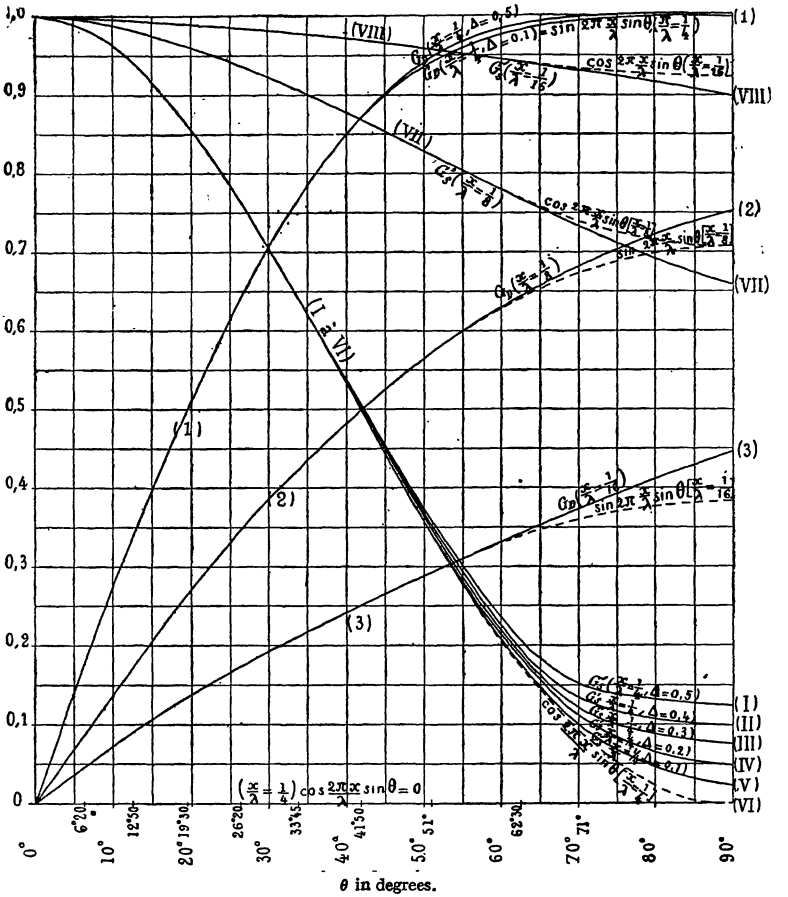
length ($x/\lambda = 1/8$), the greatest possible error will be less than 1 per cent. for G_D as well as for G_S'.

As to the errors in phase, they also may easily be considered by



$$G_D = \sqrt{\left[\sinh\frac{\Delta\phi}{2\pi}\cos\phi\right]^2 + \left[\cosh\frac{\Delta\phi}{2\pi}\sin\phi\right]^2}$$

$$G_S' = \sqrt{\left[\cosh\frac{\Delta\phi}{2\pi}\cos\phi\right]^2 + \left[\sinh\frac{\Delta\phi}{2\pi}\sin\phi\right]^2}$$

$$\phi = 2\pi\frac{x}{\lambda}\sin\theta$$

FIG. 12.

means of the expressions given above. It is easily seen that for Type D, the phase angle γ_D varies between the limits of $\pi/2$, for

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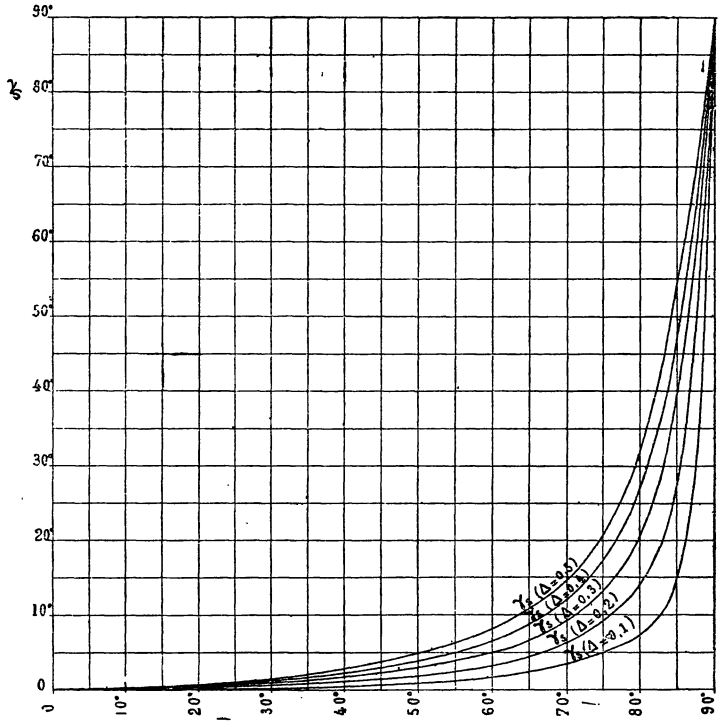
$\theta = \pi/2$ and any valu e of Δ, and $\tan^{-1} 2\pi/\Delta$ for $\theta = 0$, independently of the value of x/λ.

The phase error aris ng from neglecting the damping increases with the width of the loop but is always small for Type D—for example, when $\Delta = 0{\cdot}4$, it is at the most 3° 40′ (for $\theta = 0°$).

On the other hand, for Type S it may become very large, since γ_S, which is zero for $\theta = 0$ and any values of Δ and x/λ, becomes 90° when $\theta = 90°$ and $x/\lambda = 1/4$. For smaller values of x/λ, γ_S decreases very rapidly; for $x/\lambda = 1/8$ it is only 4°, for $x/\lambda = 1/16$, γ_S hardly reaches 1° when $\theta = \pi/2$.

Fig. 13 gives the values of γ_S as a function of ϕ.



$$\gamma_S = \tan^{-1}\left[\tan\varphi_0 \tanh\frac{\Delta\phi}{2\pi}\right]$$

FIG. 13.

The preceding investigation shows up the influence of damping on direction-finding. Primarily it must be noted that the action

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of the detector is sensibly modified but this need only be taken into consideration if the detector is of the rectifying crystal type. On the other hand, damping can give rise to considerable errors, but if care is taken to employ "Type D," which is now the only one used in practice and to adopt a wavelength longer than that at present fixed by the Convention of London, these errors become negligible. This is also the case if the size of the receiving aerials is reduced.

The object of the present paper has been especially to show the advantages of modifying the limit of 150 metres wavelength, which has been fixed for "radiophares," and to adopt a greater wavelength, such for example as 1,000 metres, but with the high sensitivity which can now be obtained with frame aerials of small dimensions by the use of amplifiers fairly practical and satisfactory results can be obtained with these frames. One difficulty only remains, resulting from the influence of wave reflections on the superstructure of the ships and of parasitic induced currents in all metallic parts of the ship such as stay wires, funnels, etc. In this connection it should be noted that larger wavelengths give rise to less trouble than small ones, for while the shrouds and metal masts are very liable to resonance with wavelengths of 100 to 150 metres, they are very much out of tune when wavelengths of 1,000 metres are used.

As to phenomena arising from reflections of the waves by metallic surfaces, the experiments of the lieutenant of the *Mesny* have shown up the remarkable fact that on an ordinary commercial vessel these reflections give rise to systematic *quadrantal* errors of the same type as the usual magnetic errors found with the compass, and in consequence the correction curve can be determined once and for all for each vessel.

In these favourable circumstances it is hoped that direction-finding on board ships will play a very important part in navigation in the future, provided that a sufficiently long wavelength can be employed.

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The Inductance of Single-Layer Rectangular Coils.

By THE EDITOR.

ONE of the results of the development of the cascade amplifier is the possibility of receiving relatively weak radio signals by means of a coil aerial without the use of an elevated antenna. Much of the transatlantic work is now received in this way. In addition to the saving of expense there is the advantage derived from the directional selective action of the coil with regard both to atmospheric disturbances and to interfering stations. The latter point is of great importance in duplex working where the interference comes from one's own transmitting station.

For constructional reasons the type of coil employed is usually rectangular; whether helical or plane spiral, the rectangular form is much more easily constructed than the circular.

The formulæ for the calculation of the inductance of rectangular coils are not so convenient as those for circular coils. In the August number of the *Jahrbuch der drahtlosen Telegraphie* a paper by A. Esau is published * in which a formula for rectangular coils is developed. The method adopted is that used by Strasser in 1905 for the inductance of cylindrical coils. It consists in adding up the self-inductances of all the turns and the mutual inductances between all the pairs of turns. The accurate formula for the mutual inductance involves benomials and logarithmic terms which are expanded in terms of the powers of the ratios g/a and g/b where g is the pitch and a and b the sides of the rectangle. Since these ratios are always small all powers above the square are neglected. The formula obtained, however, is very cumbersome, involving some twenty terms of various degrees of importance. It also necessitates reference to Strasser's constant $2 \log [(n-1)!\ (n-2)! \ldots 1]$ values of which are tabulated in Vol. 8, p. 195, of the *Bulletin of the Bureau of Standards*, U.S.A. When the two sides of the rectangle are equal, that is, when the coils are square the formula is greatly simplified and the inductance can be written $L = 8\,a\,n\,(S_1 + S_2)$ where a is the side of the square in centimetres, n the number of turns, S_1 a number depending on a/ρ (where ρ is the radius of the wire), and S_2 a number

* RADIO REVIEW, Abstract No. 73.

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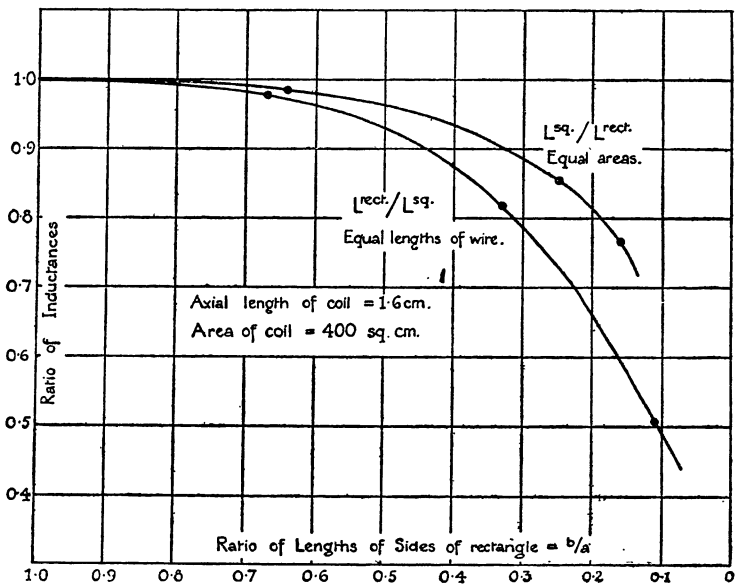
depending on n and g/a. Esau gives curves from which S_1 and S_2 can be read off if great accuracy is not required; he also gives tabulated values from which greater accuracy can be obtained.

By means of five examples the author shows that for a given length of wire the maximum inductance of a square coil is obtained when the axial length is about 0·45 of the side of the square. He also gives four examples of rectangular coils with different ratios of the sides a and b, but with a constant value of $a + b$, that is with a fixed length of wire. We have plotted his results and as the curve shows, the square has the largest inductance. Esau



also compares the square coil with a cylindrical coil with the same length of wire and shows that the latter has about 15 per cent. higher inductance than the former.

In all his comparisons Esau assumes equal lengths of wire, but we wish here to draw attention to similar comparisons based on the assumption of equal areas of coils of different shapes. If a coil is very long compared with its diameter or diagonal the value of H within it for a given current is equal to $4\pi/10$ times the ampere-turns per centimetre whether the cross-section of the coil be circular, square, or rectangular. The total flux-linkages per ampere, and therefore also the self-induction, depend on the area of the cross-section and not on its shape. For coils in which the

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diameter is not very small compared with the length, this is not strictly true, but the area forms in all cases a much better basis of comparison than the length of the wire.

We have calculated the inductance of four rectangular coils each with twenty turns of wire of 0·067 cm. diameter with a pitch of 0·08 cm. and therefore an axial length of 1·6 cm. We have kept the area constant at 400 sq. cm. The results are as follows :—

Sides of Rectangle. $a \times b$	$\frac{b}{a}$	L	$\frac{L \text{ square}}{L \text{ rect.}}$
20 × 20	1·00	207,800	1·000
25 × 16	0·64	210,500	0·986
40 × 10	0·25	242,400	0·857
50 × 8	0·16	270,000	0·77

It will be seen that in this case, *the square has the lowest inductance*, and that even when the length of the coil is only 0·08 of the side of the square,—a very far departure from the infinitely long solenoid,—the equality of area gives much closer agreement between the inductances of squares and rectangles than does equality of length of wire. The values are plotted on the same diagram as the values given by Esau.

Square and cylindrical coils are used in practice much more than rectangular ones and it is therefore of greater interest to compare the inductances of square and round coils of equal area, more especially as radio-engineers are more familiar with the calculations for cylindrical coils and generally have the necessary formulæ or curves at hand. As we have already pointed out, the inductances for equal areas are identical if the coils are very long compared with the diameter ; if the coil is not so long, *the square coil has a greater inductance than the cylindrical one*, the ratio increasing as the coil is shortened and reaching its maximum with a single turn of wire.

Taking for example the square coil of 20 cm. side and twenty turns, a cylindrical coil of the same area would have a radius of 11·28 cm. and an inductance of 202,000 cm. ; hence even in this case the square coil has an inductance less than 3 per cent. greater than the cylindrical coil. A single square turn 20 × 20 cm. of 0·067 cm. wire has nearly 8 per cent. greater inductance than the circular turn of equal area.

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An Investigation of the Internal Action of a Triode Valve.

By W. H. ECCLES, D.Sc., M.I.E.E.

(*Continued from page 77.*)

EFFECT OF THE FALL OF POTENTIAL ALONG A FILAMENT.

When the cathode is a filament heated electrically there is a fall of potential along the filament amounting to four or six volts in small receiving triodes and to twenty or forty volts in large ones. It is necessary to examine the effect of this fall of potential upon the lumped characteristic. In Fig. 13, FF′ represents the length of a filament, F being the negative end, of a cylindrical triode. Let us suppose that, on being given a definite value of the anode and grid voltages relative to the negative end, a plane perpendicular to the filament is drawn at any point of it, and that the voltages of these electrodes above that of this point of the filament are represented by ordinates on the corresponding point of FF′. For instance, at the end F of the filament the end of the anode is e_a volts above the filament, and the end of the grid is e_g volts above; at the end F′ the anode is $e_a - e_f$ volts above the corresponding point of the filament, and the grid is $e_g - e_f$ above, where e_f is the voltage applied to the filament for maintaining its current. In order that the diagram may at once give the lumped voltage we

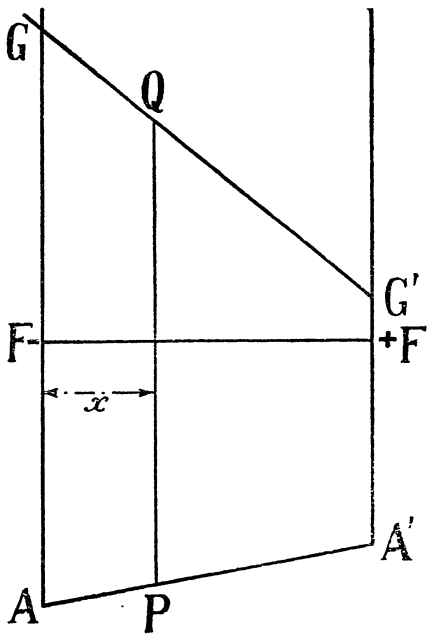

FIG. 13.

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shall set g times the grid voltage to scale up the page, and the anode voltage to the same scale down the page. This is done at G and G′, at A and A′. It is evident immediately that the relative voltages in any plane, and the corresponding lumped voltage, are given by joining GG′ and AA′ by straight lines and then drawing an ordinate through the filament abscissæ concerned. At a point distant x from the end F the lumped voltage relative to the filament is given by the length PQ. Since the gradient of the anode line is e_f/l and that of the grid line ge_f/l, the anode is $e_a - xe_f/l$ volts and the grid $ge_g - xge_f/l$ "transferred" volts, above the filament in the plane distant x from the negative end, l being the length of the filament. The lumped voltage is, therefore,

$$PQ = e_a + ge_g - (1 + g)\, e_f x/l$$

in any plane, and the electron current in this plane is proportional to the three-halves power of this expression. The total current at any given adjustment is given by integrating the ordinate PQ throughout the area AA′G′G. The formula is easily obtained, but is not required here.

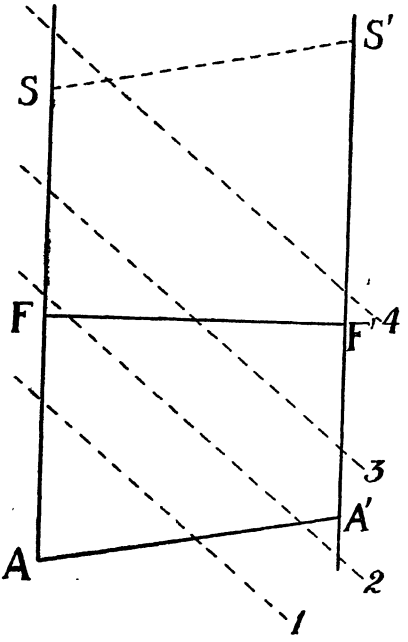

FIG. 14.

As the grid voltage rises the line GG′ moves up the page parallel to itself; as the anode voltage rises the line AA′ moves *down* the page parallel to itself. Keeping the anode voltage fixed, and varying the grid voltage from extreme negative values to extreme positive values of potential, we see that the grid lines take successive positions such as those numbered 1, 2, 3 in Fig. 14. The area swept over by the moving line is at first a rapidly growing triangle—then a rhomboid growing steadily, and then a slowly growing five-sided figure when the line SS′ is intersected. This line represents the saturation level. It is drawn parallel to AA′ because the saturation current is reached at each end at the same relative voltage, that is, the voltage AS equals the voltage A′S′.

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Inspection of the areas swept over by the moving line shows, without elaborate calculation, that the effect of the fall of potential along the filament is practically confined to the knees of the lumped characteristic—the middle portion is not affected. This conclusion is exhibited graphically in Fig. 15, where the actual curve that would be obtained by an experimenter using one end of the filament as his zero of potential is shown as a mean between two ideal curves that would be obtained from the same triode if, first, all the filament were at the potential actually possessed by one end, and, second, all at the actual potential of the other end.

THE STRAIGHT PART OF CHARACTERISTIC CURVES.

For many practical purposes the straight part of the triode characteristic is the most important part, and there are many types of tube in which it is longer than the curved parts. In some cases the three-halves power law holds over only about a sixth part of the characteristic. It is very desirable to have an explanation of this striking departure from the three-halves power law, for in the absence of an understanding of the causes the designer works in the dark. There are many factors to which the phenomenon might be attributed—factors omitted from the analysis of the preceding pages. Among these are the finiteness in the length of the electrodes and the consequent stray electric field, the magnetic effect of the filament current, the flow of the electron current to right and to left along the filament, the distribution of velocity of the electrons at emission, the production of secondary electrons, the space charge that accompanies the flow of the grid current, the cooling of the ends of the filament, and others. We have investigated already the effects of the fall of potential along the filament and have found that it cannot have

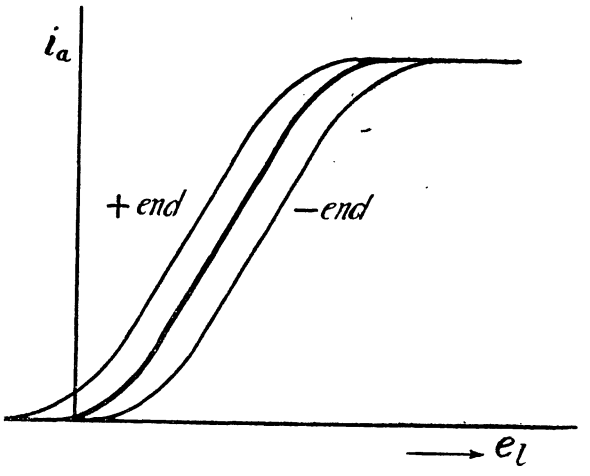

FIG. 15.

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any appreciable influence in producing the straight part of the characteristics; and upon close examination it is found that only one of the factors enumerated above can account for the facts; this is the cooling of the ends of the filament, or, in other words, the rise of temperature from the ends to the centre of the filament.

The explanation to be offered applies to all forms of triode utilising heated filaments as cathodes, and does not depend on whether the filament is straight or folded; but for simplicity we shall assume that we are dealing with a cylindrical triode possessing a straight axial filament. The middle parts of the filament are surrounded by the anode, which serves incidentally as a good reflector of the heat radiated from the filament, and therefore tends to keep up the temperature of the centre portions. The ends of the filament are, on the other hand, rather strongly cooled by the leads that support it and also by the opportunity for radiation. Now, the electron current that can be drawn from a hot filament increases rapidly with rise of temperature—for example, the saturation current per unit length of a certain filament while at a uniform temperature of 2,200° K was 15 mA, and this was attained at 30 V, while the same filament at 2,400° K gave a saturation current of 110 mA at 115 V. A difference of 200° in temperature between the middle and ends of a filament in a triode is not at all unlikely, and therefore in such an instrument the ends yield their maximum current at a lumped voltage of 30 V and cannot contribute more though the voltage be raised. Up till that voltage every point of the filament would obey the three-halves power law, but after that the ends yield 15 mA while the centre portions continue to obey the law. But as the lumped voltage is raised further and further more and more of the filament attains saturation and ceases to contribute further increases of current. Evidently the law which the total current obeys will depend greatly upon the law according to which the temperature is distributed along the filament, and it is clear that the filament as a whole will not give its final saturation current till the

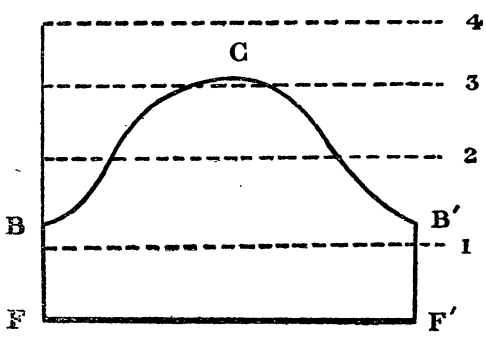

FIG. 16.

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voltage is raised to the saturation value corresponding to the temperature of the hottest part of the filament. All this is represented graphically in Fig. 16. In this figure FF′ represents the length of the filament, and the ordinates of the curve BCB′ represent values of the saturation current per unit length at the corresponding points of the filament.

Since it has been shown that the fall of potential along the filament is not fundamentally concerned in the present problem we shall suppose the filament is at uniform potential throughout its length and shall therefore represent any lumped voltage between it and the other electrodes by a straight line parallel to FF′. Such lines are drawn and marked 1, 2, 3, 4 in the figure; they are placed at heights that represent to scale the electron current per unit length corresponding to the voltage, that is, their heights are proportional to the three-halves power of the lumped voltage. At the position marked 1 the voltage is such that even the ends of the filament are not giving their saturation current, which is equal to FB; and every portion of the filament is yielding current at equal rates per unit length and according to the three-halves power law. At the position 2 we have a state of affairs in which large portions near the ends of the filament are giving their various saturation currents while the middle portion still follows the three-halves power law in responding to rise of voltage. At the position 3 almost every part of the filament is giving its saturation current, and at position 4 the current has ceased to respond to changes of the lumped voltage. At any stage the whole current i_a is equal to the area under the line and within the curve.

Let l be the length of the filament, y the length of the centre unsaturated portion in any general position of a line such as that numbered 2, i_u the electron current being taken per unit length of the unsaturated portion, e_l the lumped voltage throughout the length of the triode, i_a the total current from anode to cathode. Since the filament is all at one potential we are free from anxiety about the zero of the lumped voltage and write, therefore,

$$i_u = A' e_l^{\frac{3}{2}}.$$

Imagine that the voltage undergoes the increment de_l; the line in the diagram will rise and add to the area underneath it an amount equal to the length of the unsaturated portion multiplied by the increase in the electron current throughout that portion. The total current increases by the amount di_a, and we have

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$$di_a = y di_u.$$

By aid of the preceding equation we obtain

$$\frac{di_a}{de_l} = \frac{3}{2} A' y e_l^{\frac{1}{2}}.$$

This differential equation is the expression of the law connecting i_a, e_l, and y.

In position 1, y is l, and we can then integrate the equation and obtain

$$i_a = l A' e_l^{\frac{3}{2}}.$$

In position 2 the length of y varies as the line rises and, therefore, the equation cannot be integrated till the law of variation is given for the particular filament in use. In position 3 the equation is about to be put out of action by the fact, not expressed in it, that the temperature has a limit. In position 4 the equation is completely out of action; obviously the area of the whole curve FBCB'F' represents the total saturation current of the tube.

The determination of y, which implies the determination of the temperature at every point of the filament, if it had to be done from the fundamental physical laws of the conduction and radiation of heat, would demand a complete knowledge of the dimensions and properties of the filament substance and of the reflecting powers of its surroundings; consequently we leave the connection between i_a, e_l and y in the form of a differential equation. But it is interesting to reverse the process and to inquire how the electron current per unit length (and inferentially the temperature) would have to vary from point to point of the filament in order to give a specific shape to the characteristic. The designer is able to control the temperature distribution by, for example, using a filament of variable section and by altering the configuration of the reflecting surfaces. Therefore let us inquire into the variation of electron current needed to make a large portion of the characteristic curve a straight line. Let the equation of this straight part be

$$i_a = h_o + h_a e_l$$

where h_o and h_a are constants on this occasion.

Then

$$\frac{di_a}{de_a} = h_a,$$

and therefore

$$h_a = \tfrac{3}{2} A' y e_l^{\frac{1}{2}}$$

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gives the connection between y and e_l along the straight portion. In terms of the electron current per unit length this becomes

$$h_a = \tfrac{3}{2}A'y(i_u/A')^{\frac{1}{3}} = \tfrac{3}{2}A'^{\frac{2}{3}}yi_u^{\frac{1}{3}}.$$

By aid of this equation the curve of Fig. 17 is constructed to exhibit the highest electron current possible at each point of the filament. The parallel straight line boundaries marked F B, F' B' are drawn a distance l apart where the length l is the active part of the filament. The upper boundary line parallel to the base has yet to be determined. To do this we may return to the differential equation

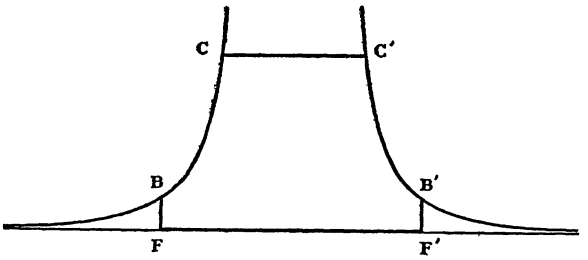

FIG. 17.

$$di_a = ydi_u$$

and eliminate i_u by aid of the last equation. First put this in the form

$$i_u = cy^{-3}$$

for brevity, and notice that if i_{a1} represent the total current across the vacuum at the instant when the ends of the filament reach saturation values, then at that instant

$$i_{a1}/l = cl^{-3}$$

in accordance with the above equation. Thus

$$i_{a1}l^2 = c.$$

Now write

$$\begin{aligned} di_a &= yd(cy^{-3}) \\ &= -3cy^{-3}dy. \end{aligned}$$

On integrating we get

$$i_a = \frac{3}{2}\frac{c}{y^2} + \text{constant}.$$

When $y = l$, $i_a = i_{a1}$, therefore,

$$i_{a1} = \frac{3}{2}\frac{c}{l^2} + \text{constant}.$$

Hence

$$i_a - i_{a1} = \frac{3}{2}c\left(\frac{1}{y^2} - \frac{1}{l^2}\right).$$

Upon eliminating c by aid of the previously found relation we have

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$$\frac{i_a}{i_{a1}} - 1 = \frac{3}{2}\left(\frac{l^2}{y^2} - 1\right),$$

or

$$\frac{y^2}{l^2} = \frac{3i_{a1}}{2i_a + i_{a1}}.$$

This equation gives the fraction of the length of filament still unsaturated when the total current is known by measurement. For example, if $i_a = 9i_{a1}$ at the extreme end of the straight portion of the characteristic, that is to say, if in a certain tube the length of the straight portion of the characteristic is such that the current at the upper end is nine times that at the lower end, we have

$$\frac{y^2}{l^2} = \frac{3}{18 + 1},$$

or

$$y = 0{\cdot}397l.$$

In words, the central four-tenths of the filament is at a practically uniform temperature which is higher than that of the portions of filament on each side of it.

The writer takes this opportunity of thanking Mr. H. Davies for making the measurements involved in this paper and in the drawing of the characteristics of Figs. 11 and 12.

The British Association Meeting at Bournemouth.

The Three-Electrode Thermionic Valve as Alternating Current Generator.

By Professor C. L. FORTESCUE.

(*Continued from page* 88.)

3. Theory of the Combination of Valve and Capacity-Inductance Circuit.

In designing the valve and circuit two things have to be kept in mind. In the first place the conditions must always be such that any incipient oscillation in the capacity-inductance circuit will cause sufficient power to be supplied from the valve for the oscillation to be built up from the indefinitely small initial values to relatively large amplitude. In the second place

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the circuit arrangements should be such that the maximum power is taken from the tube, so setting up oscillations of the greatest possible amplitude, in which connection it may be remarked that with bad proportioning of the circuit and the valve, the current generated may reach a stable maximum value long before the possible maximum power output from the tube is attained. Bad design of this kind is obviously wasteful, as it leads to the use of unnecessarily large and expensive valves.

Referring to the simple circuit arrangement of Fig. 3, it will be seen that in the course of one cycle of the oscillating current in the capacity-inductance circuit, the effective voltage both between the grid and the filament and between the positive electrode and the filament are varying. In Fig. 6 the variation of these two voltages is plotted for one cycle in the correct relative phases to the current in the inductance, the positive direction of the current in the inductance being from the point *a* to the point *O*, and on to the point *b* (Fig. 3). With regard to the tube, the positive direction for the voltages at both the positive electrode and the grid is when the filament is negative. In order to determine the nature of the current in the part *Ob* of the inductance *L* it is necessary to refer to the characteristics of the valves. These may be plotted as in Fig. 2, but are preferably drawn out, as in Fig. 7, a method adopted in H.M.S. *Vernon* in 1915. In this figure the voltage at the grid is plotted horizontally, the voltage at the positive electrode vertically, and the current at the positive electrode is drawn in as a series of contours of constant current.

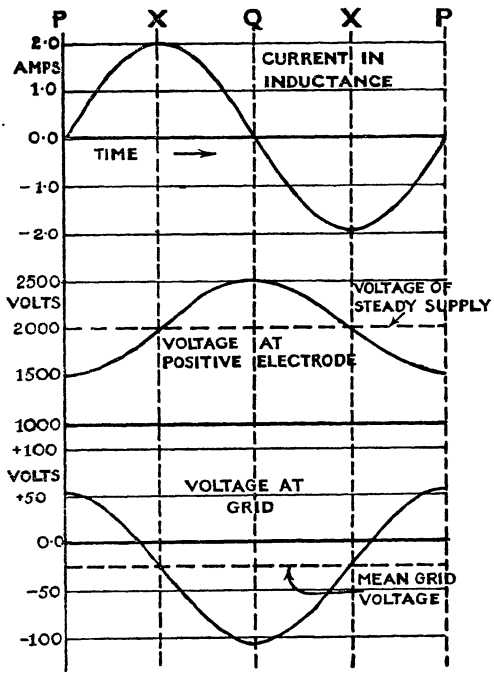

FIG. 6.

The first point of the cycle of Fig. 6 is a point where the voltage at the grid is a maximum and that at the positive electrode a minimum. This will correspond to a point *P* in Fig. 7. After one quarter of a cycle has been passed through the voltage at both the grid and the positive electrode will be at the normal values as maintained by the batteries. This state corresponds to the point *X* of Fig. 7 (which also corresponds to the point *X* of Fig. 2). After one-half cycle has been passed through, the point *Q* of Fig. 7 will have been reached. After three-quarters of a cycle, a return is made

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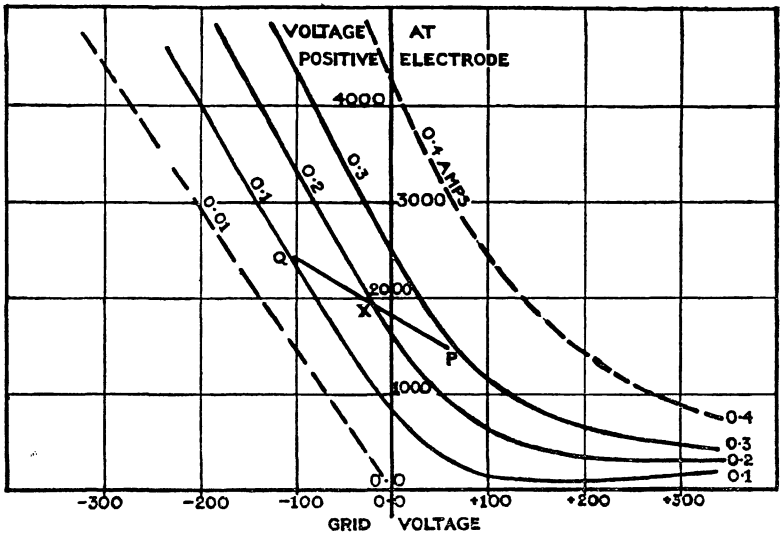

FIG. 7.

to the point X, and back again to the point P on completion of the whole cycle. Since the alternating components of the voltages in Fig. 6 differ in phase by 180°, the points P, X and Q of Fig. 7 will lie on a straight line, which has been called the "Oscillation Line." The way in which this line cuts the contours in Fig. 7 shows the variation of the current in the part Ob of the inductance L. This variation has been plotted in Fig. 8 in its correct phase relation to the current in the inductance. It will be seen from an inspection of the second curves of Figs. 6 and 8 that the alternating component of the current flowing in at O and out at b (Fig. 3) is opposite in phase to the alternating component of the voltage between these two points. The conditions chosen for the diagrams represent, therefore, a supply of alternating power to the inductance. Had the oscillation line been drawn as in Fig. 9, the phase of the current would have been reversed, and power would have been abstracted

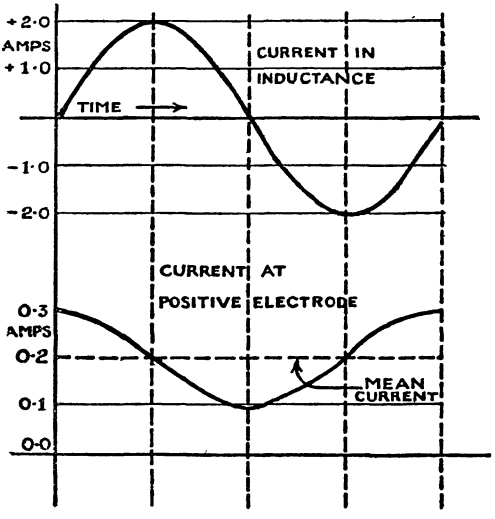

FIG. 8.

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from the circuit. One condition necessary for the building up of a small incipient oscillation is, therefore, that the oscillation line should lie as in Fig. 7, and not as in Fig. 9. Another condition is that the alternating power supplied to the circuit should exceed the sum of the power expended in the circuit and the power abstracted from the circuit (by any means whatever). The power expended in the circuit is due to the main oscillating

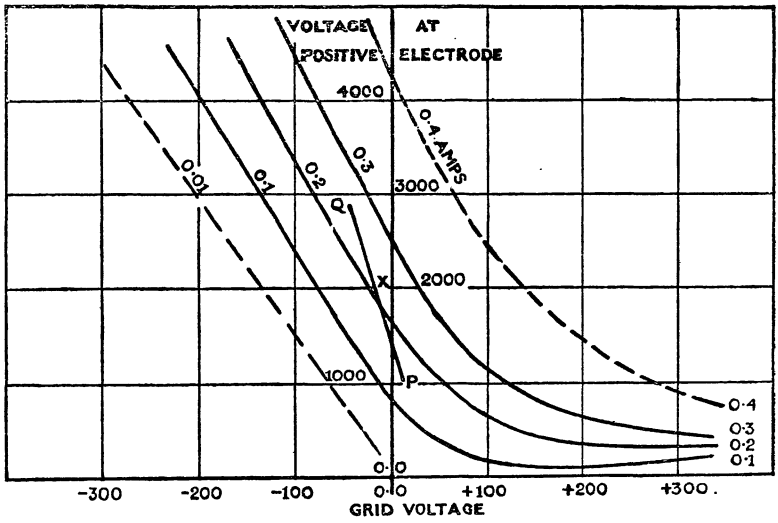

FIG. 9.

current in the inductance and the condenser, and to the exciting valve current in the part *Ob* of the inductance. With the simple circuit the power abstracted is only that required to vary the voltage of the grid, observing that the grid current is usually in phase with the alternating voltage across the part *aO* of the inductance.

As a very good first approximation, which is good enough for most designing purposes, the following assumptions may be made:—

(*a*) The power expenditure arising from the passage of the exciting current from the valve through the part *Ob* of the inductance may be neglected in comparison with the whole loss due to the main oscillating current.

(*b*) The power abstracted from the circuit to operate the grid may be neglected in comparison with the loss due to the main oscillating current.

(*c*) The resistance component of the voltage across each part of the inductance may be neglected in comparison with the reactance component; *i.e.*, the relative phases of the voltage and current may be taken as differing negligibly from 90°

(*d*) The amplitude of the incipient oscillation may be assumed to be so

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small that the characteristic curves may be taken as straight lines over the whole range under consideration.

(*e*) The alternating component of the current to the positive electrode may be assumed small compared with the main oscillating current, and to cause only slight changes in the alternating voltages applied to the grid and positive electrode.

With these assumptions the conditions necessary for the maintenance of oscillations can be calculated easily. Let δI be the R.M.S. value of the incipient alternating current in the inductance. The corresponding R.M.S. voltage, δV, across the whole inductance is

$$\delta V = L\omega.\delta I \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where $\omega = 2\pi$ times the frequency.

Let the voltage across the part aO of the inductance be some fraction of δV, viz., $a\,\delta V$, and that across the part Ob some other fraction, viz., $b\,\delta V$; the only limitations to a and b being

$$a + b \not> 1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Let k_1 be the rate of increase of the current at the positive electrode with respect to the increase of the grid voltage, and k_2 the rate of increase with respect to the voltage at the positive electrode. The alternating component of the valve current through the part Ob of the inductance is then

$$k_1 a.\ \delta V - k_2 b.\ \delta V$$

If δW denotes the mean power supplied to the circuit, then

$$\begin{aligned} \delta W &= b.\ \delta V\ (k_1 a.\ \delta V - k_2 b.\ \delta V) \\ &= (k_1 ab - k_2\, b^2)\ \delta V^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3) \end{aligned}$$

With the foregoing assumptions, the power expenditure in the circuit is $\delta I^2 R$, R being the effective resistance of the oscillatory circuit.

The conditions necessary for a small oscillation to build up to a large one are therefore

$$(k_1 ab - k_2\, b^2)\ \delta V^2 > \delta I^2 R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

But $\delta I = \delta V/L\omega$, and so the condition becomes

$$k_1 ab - k_2\, b^2 > R/L^2\omega^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

And putting $\omega^2 = 1/LC$, which is nearly true, the condition reduces to

$$k_1 ab - k_2\, b^2 > RC/L \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

or

$$Labk_1 > RC + Lb^2\, k_2 \quad . \quad . \quad . \quad . \quad . \quad (6a)$$

With power valves the term Lb^2k_2 is sometimes much greater than the term RC, and when this is the case the approximate conditions for the maintenance of oscillations become $a/b > k_2/k_1$, which is simply an expression of the requirement that the oscillation line must lie as shown in Fig. 7 and not as in Fig. 9.

Equation (3) is also of interest in that it gives a value for the "negative resistance" of the valve. Putting $\delta V = L\omega\ \delta I$, the power supplied to the circuit is

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$$\delta W = (k_1 ab - k_2 b^2)\, L^2\omega^2\, \delta I^2$$
$$= \frac{L}{C}(k_1 ab - k_2 b^2)\, \delta I^2$$

from which it follows that the negative resistance is

$$(R -) = \frac{L}{C}(k_1 ab - k_2 b^2) \quad \ldots\ldots\ldots\ldots \quad (7)$$

The required condition for the maintenance of oscillations is that this negative resistance shall exceed the actual resistance, R, *i.e.*, that

$$\frac{L}{C}(k_1 ab - k_2 b^2) > R \quad \ldots\ldots \quad (6b)$$

which is identical with equation (6).

Assuming that the necessary conditions are complied with, any small oscillation that may be started by the closing of a switch or by any other means, will gradually increase in amplitude. The corresponding oscillation line will lengthen proportionally and in course of time will extend into regions where the values of k_1 and k_2 are no longer constant throughout the whole of the cycle and the alternating component of the current from the valve will be no longer a sine wave. The effect will be particularly marked when the oscillatory current reaches such a value that the voltage at the positive electrode is reduced almost, or quite, to zero at the beginning of the cycle. In consequence of this irregularity the power supplied to the circuit from the valve will increase less rapidly than the square of the current in the main oscillatory circuit. Stable conditions where the power supply is equal to the power expenditure will thus be reached quickly and no further increase of the current will take place unless the resistance of the circuit is reduced.

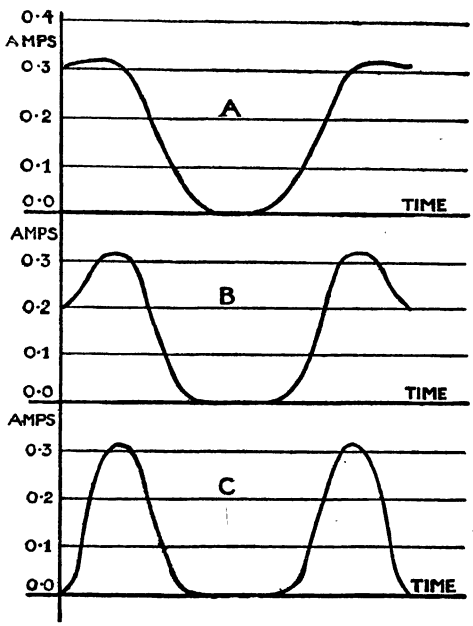

FIG. 10.

In Fig. 10 three cases have been taken. The circuit for which the curves are plotted consists of an inductance of 3,050 micro-henries and a capacity of 3,000 cm., so giving a wave length of about 6,000 metres. The connections to the valve are such that $b = 0{\cdot}26$, $a = 0{\cdot}04$, and the valve characteristics assumed are the same as those of Fig. 7. The curve A has been drawn for a

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current of 3·7 amperes, which will reduce the voltage at the positive electrode to 700 volts at the beginning of the cycle. The power supplied to the circuit will be about 116 watts and the current would be stable at this value if the resistance of the circuit was 11·8 ohms. In curve B a larger oscillatory current of 4·85 amperes is assumed, which would reduce the voltage at the positive electrode to 300 volts. A very marked kink is then appearing in the top of the wave of exciting current. The power supplied to the circuit will be about 137 watts and the current would be stable at this value if the resistance of the circuit was 5·8 ohms In curve C the oscillatory current has been taken as 5·7 amperes, which will just reduce the voltage at the postive electrode to zero. Compared with the curve B the irregularity of the wave will be much greater, and the power supplied to the circuit will be reduced both actually and relatively, with the result that this current could only be maintained if the resistance was reduced to about three ohms. These curves show quite clearly why it is that with a valve generator the current increases but little when the resistance of the circuit is reduced, unless some alteration is made to the adjustments. They also illustrate a self-protecting property of the valve. If the load is taken off there is a small increase in the current, accompanied by a reduction of the mean power taken from the supply. In curve A the mean current at the positive electrode is about 0·17 ampere, but in curve C it is only 0·12 ampere.

For the particular conditions in which the mid-point of the cycle of maximum amplitude is at the mid-point of the characteristics, the R.M.S. value of the exciting current from the valve is $\frac{I_e}{2\sqrt{2}}$, I_e being the saturation electron current; and the R.M.S. value of the voltage across the part Ob of the inductance is $\frac{V_0}{\sqrt{2}}$, V_0 being the steady voltage applied to the positive electrode.

The maximum power that can be obtained from the tube is then

$$\frac{I_e}{2\sqrt{2}} \cdot \frac{V_0}{\sqrt{2}} = \frac{1}{4} I_e V_0.$$

If I and V are the R.M.S. values of the alternating current and voltage in the oscillatory circuit, the stable maximum conditions are then approximately

$$I^2R = \frac{1}{4} I_e V_0.$$

But $I = \frac{V}{L\omega}$, and if the oscillation line just stops at the horizontal axis,

$$bV = \frac{V_0}{\sqrt{2}}.$$

Hence

$$b^2 = 2 \frac{V_0}{I_e} \cdot \frac{RC}{L} \quad \ldots\ldots\ldots \quad (8)$$

This equation gives the suitable value for b, and the corresponding value of a for the maintenance of the oscillations follows from equation (6).

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The average current taken from the supply is $\frac{1}{2} I_s$ at the steady voltage V_0. Hence the efficiency of the valve, neglecting the power supply to the filament, is 50 per cent.

This, however, is by no means the highest possible efficiency. Any arrangement of the valve and circuit that leads to an irregular wave of current giving a considerable power to the circuit, but having at the same time a lower arithmetic mean will give a much higher efficiency than 50 per cent. If a steady negative voltage is applied to the grid so that the midpoint of the cycle is towards the bottom of the characteristics, efficiencies up to as high as 75 per cent. can be obtained. A battery may be used for this purpose, but the circuit shown in Fig. 5 is preferable. Here the small rectified current from the grid passes through the resistance R_3, and so automatically maintains the grid at a negative voltage depending upon the amplitude of the oscillations.

This theory of the action of the circuits is applicable to any form of circuit. If, for example, a mutual coupling to the grid is used, the grid voltage can still be expressed as a fraction of the voltage across the main inductance. If M is the mutual inductance, $a = \frac{M}{L}$ and the condition for the building up of the oscillations is

$$Mbk_1 > RC + Lb^2k_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

4. A Short Description of certain Valve Transmitting Sets used for W/T in the Naval Service.

Most of the valve transmitting sets in the Naval Service have been designed to work, as far as possible, from the power supply of existing spark telegraphy sets. This power supply is in the form of a high-voltage single-phase alternating current of frequency from about 100 cycles per second upwards. To use this supply it is, therefore, necessary to fit rectifiers which will convert the alternating supply into a direct current supply. The rectifiers used are two-electrode valves, differing from the three-electrode valves only in that the grid electrode is omitted. Fig. 11 shows a simple method of connecting up a two-electrode valve for this purpose. During the half cycles, when the positive electrode P is positive to the filament, negative electrons are drawn from the filament. During the other half cycles no reverse current can pass. Consequently there is a deficit of

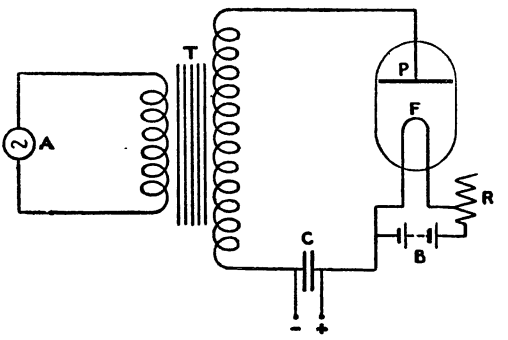

FIG. 11.

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negative electrons on the plates of the condenser connected to the filament of the valve. The terminals of the condenser C can then be used as a direct current supply. By increasing sufficiently the capacity of the condenser the uniformity of the D.C. supply can be increased to any desired extent. The numerical relationships of rectifiers of this type have been given recently by the author.*

An improvement on the simple circuit of Fig. 11, involving the use of two valves, has generally been used. Fig. 12 shows such a typical circuit arrangement. With this system one valve is operative during each half cycle, and for a given uniformity of the direct current supply, the capacity required in the condenser C is much less. The facts that the midpoints of the secondary windings of the spark set transformers were already connected to earth, and that the whole secondary voltage was usually in excess of that required for the valves, were additional reasons for the adoption of the two-valve system.

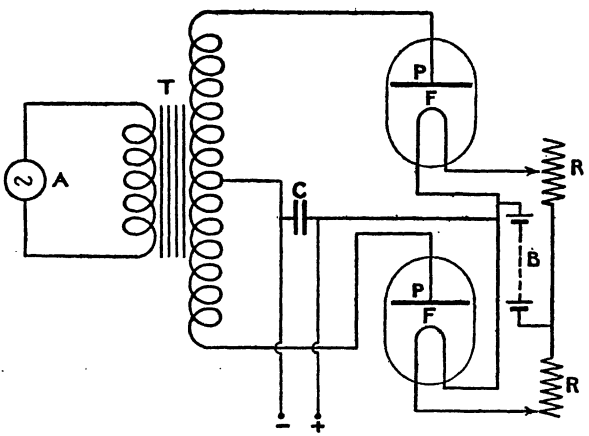

FIG. 12.

For the oscillating circuit two systems have been used: one in which the aerial has constituted the capacity in the circuit, and the other an arrangement of coupled circuits, in which the aerial circuit is separately tuned and is loosely coupled to an oscillating circuit connected to the valve.

When using the aerial as the capacity, the circuit arrangement is as shown in Fig. 5, with the addition of the necessary switch for the control of the oscillations in accordance with the Morse signals to be sent. This switch has to perform two functions, viz., to break the primary supply to the transformer, and to throw the earth connection of the aerial coil over to the receiving instruments. Magnetically operated switches have generally been used for this purpose, which are controlled by the operator in the receiving compartment by a single Morse key of the ordinary type.

Figs. 13 and 14 are photographs showing the general arrangement of one of the valve transmitting sets used in the Naval Service.

In the centre of Fig. 13 are the two rectifying valves with the controlling rheostat and instruments on the left, the whole unit being mounted on porcelain insulators. The alternating supply comes in on the extreme left;

* Paper read before the Physical Society of London, June 27th, 1919. (See RADIO REVIEW, Abstract No. 12.)

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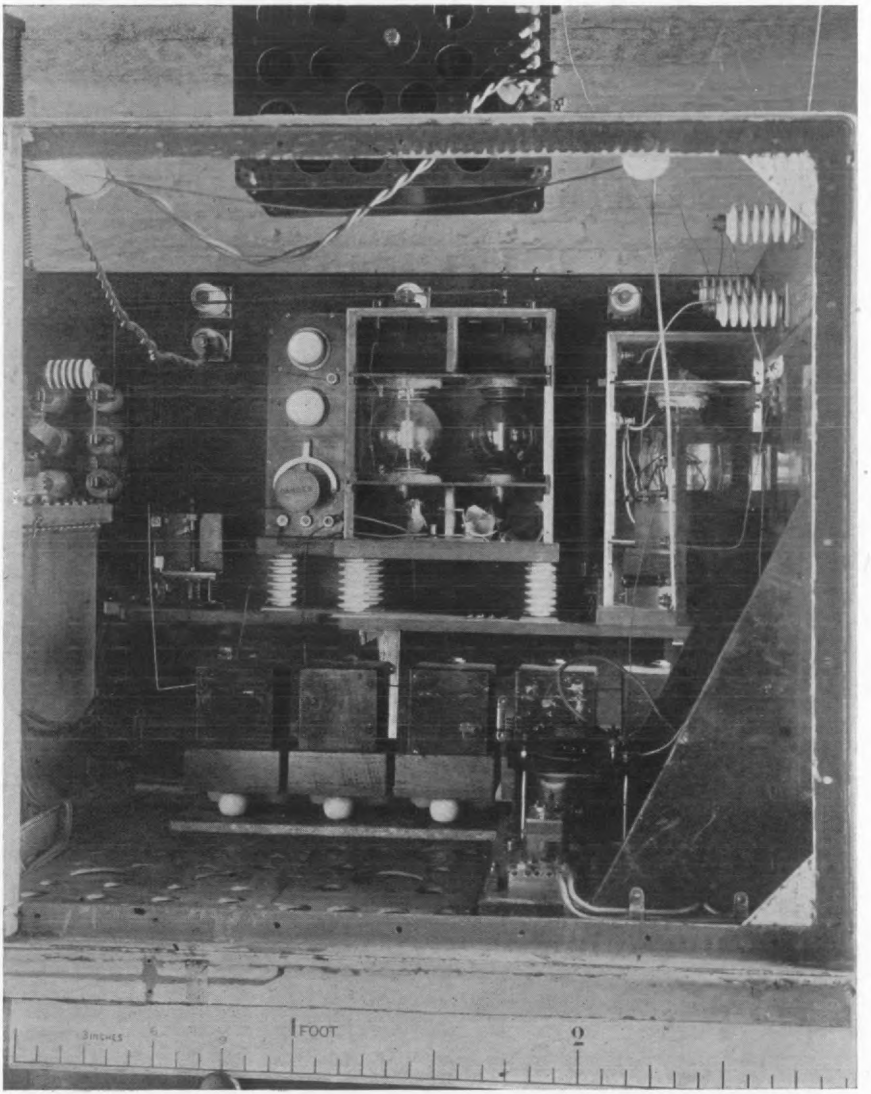

FIG. 13.

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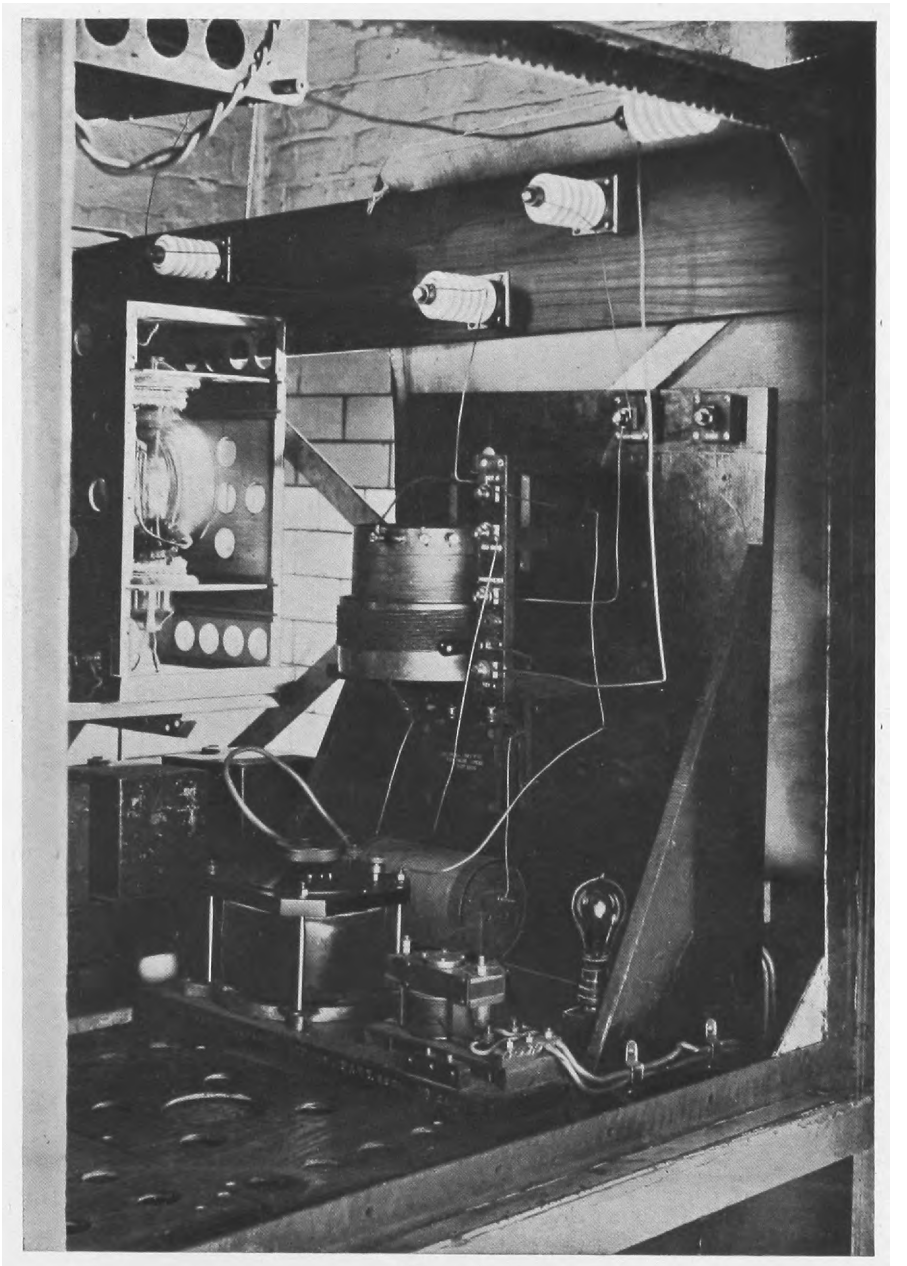

FIG. 14.

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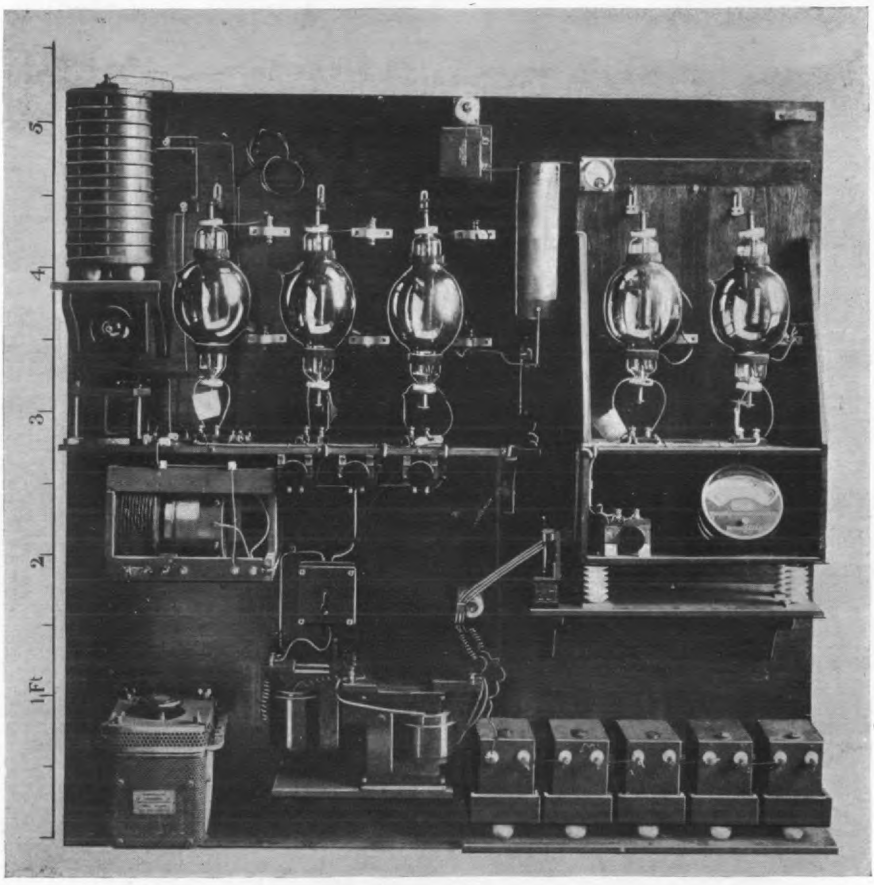

Fig. 15.

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below the rectifier unit are the four condensers used for smoothing out the current from the rectifiers. The single oscillating valve is placed to the right of the rectifiers and appears on the extreme right of Fig. 13. Fig. 14 shows the additional apparatus required to couple the valve to the existing aerial circuit, together with a further view of the oscillating valve on the left. In the centre of Fig. 14 is the grid coupling coil. One part of this is connected in series between the aerial tuning inductance and earth. The upper part is connected to the grid, and in this set a variable condenser is used in parallel with this inductance in order to tune the grid circuit. The cylindrical object at the back of this condenser is the resistance R_3 of Fig. 5. The small magnetic switch in the front of Fig. 14 is the switch changing over the aerial connections from the earth connection to the receiving instruments in the interval between the Morse signals.

Fig. 15 shows the complete set of additional apparatus required for use with a much more powerful installation.

The complete rectifier unit is on the right, with the smoothing condensers below.

Three oscillating valves are used in parallel, the three filament regulators being situated immediately beneath them.

The grid coupling coil and grid circuit tuning condenser are in the centre on the left, and the R_3 resistance is in the left-hand top corner. At the bottom, on the left, is the alternator field regulator, and between it and the smoothing condensers are two transformers supplying the filament current for the valves.

In conclusion, the author would like to add a word of thanks to the staff of the W/T Department of H.M. Signal School, Portsmouth, for the assistance given in the preparation of this paper.

A Trigger Relay Utilising Three-Electrode Thermionic Vacuum Tubes.

By W. H. ECCLES, D.Sc., and F. W. JORDAN, B.Sc.

Paper read before Section G (Engineering) of the British Association.

In a well-known method of using a triode for the amplification of wireless signals an inductive coil is placed in the filament-to-anode circuit, and another coil magnetically coupled with this is introduced into the filament-to-grid circuit. This "back-coupling," as it is sometimes conveniently called, if it is arranged in the right sense, greatly exalts the magnification produced by the tube in any alternating E.M.F. applied to the grid; for the

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induced E.M.F. passed back to the grid is in correct phase relation to add directly to the original alternating E.M.F. applied there. If, instead of using inductive retroaction of this kind, we attempt to use resistance back-coupling, then the retroactive E.M.F. applied to the grid is exactly opposite in phase to the original alternating E.M.F., and the amplifying action of the triode is reduced. Since, however, one triode can produce opposition in phase in the manner indicated, it is clear that two or any even number of similar triode-circuits arranged in cascade can produce agreement in phase. Hence we conclude that retroactive amplification can be obtained by effecting a back-coupling to the first grid from the second, fourth, and so on, anode circuit of a set of triodes arranged in an ohmically-coupled cascade.

It is possible to take advantage of the fact above stated for obtaining various types of continuously-acting relay, but the purpose of the present communication is to describe what may be called a one-stroke relay which, when operated by a small triggering electrical impulse, undergoes great changes in regard to its electrical equilibrium, and then remains in the new condition until re-set.

In what follows, the circuit comprising the space in the tube between anode and filament, the external conductors and the source of E.M.F., will be called the anode circuit, and the current flowing in it the anode current. The circuit comprising the space in the tube between the grid and the filament, external conductors and a source of E.M.F., will be called the grid circuit, and the current flowing in it the grid current.

The operation of the relay is most easily explained when two tubes, each with resistances and battery in its plate circuit, and with a resistance and battery in its grid circuit, are used and interconnected in the manner shown in Fig. 1.

The electrical stimulus from outside which it is desired to detect and magnify is applied in the grid circuit in the first tube so as to make the grid transiently more positive in potential relative to the filament. This causes an increase of current in the plate circuit of the first tube, and consequently an increase of the P.D. between the terminals of the plate circuit resistance. This increased P.D. is transferred to the grid circuit of the second tube in such a manner that the grid becomes more negative than before relative to its filament. Consequently the plate current of the second tube decreases, and the P.D. between the terminals

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of its plate circuit resistance decreases also. This decrease of P.D. is now transferred to the grid circuit of the first tube in such a manner that it tends to make the grid more positive relative to the filament. The result of these processes is that a positive stimulus from outside given to the grid of the first tube initiates a chain of changes which results finally in the plate current of the first tube attaining the highest value possible under the E.M.F. of its battery, and the plate current of the second tube falling to its lowest possible value. This condition, therefore, persists after the disappearance of the initial stimulus. In the initial condition, with the two-tube arrangement just described, the plate current of the first tube is made very small, and that of the second tube large; after the reception of the outside stimulus on the grid of the first tube the final condition is a large plate current in the first tube and a small plate current in the second tube. Either the decreases or the increases of plate current can be used for indicating. In order to restore the initial conditions it is easy to interrupt for an instant the linkage between the tubes, or to stop the operation of one or both of the tubes, as, for instance, by dimming its filament.

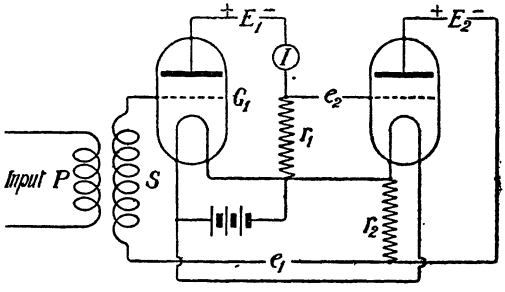

FIG. 1.

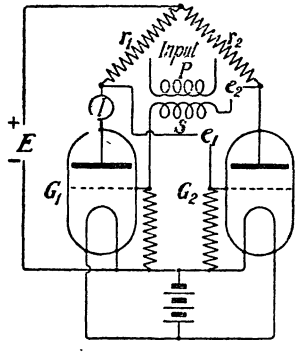

FIG. 2.

The external stimulus is led into the primary P of transformer PS, of which the secondary is connected to grid G_1. The plate circuit of this first tube contains the indicating instrument I, such as an ammeter or a moving tongue relay. The resistance r_1 in the plate circuit of the first tube has its terminals connected to the filament and grid of the second tube. Similarly, the resistance r_2 in the plate circuit of the second tube has its terminals connected

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to the filament and the grid of the first tube. The plate circuits contain batteries E_1, E_2, and the grid circuits batteries e_1, e_2. The following values are typical, and show the performance of the relay :—

E_1=78 volts. E_2=74 volts.
r_1=22,000 ohms. r_2=12,000 ohms.
e_1=31 volts. e_2=17·5 volts.

The change in the indication of an ammeter at I is from 0 — 2·5 micro-amperes.

The sensitiveness of the arrangement depends on the transformer PS to some extent. Using a telephone transformer of the kind made for Army C Mk. III. Amplifier with 20 ohms resistance in the primary, and with the primary connected to a Brown telephone of 60 ohms resistance, the relay is operated with certainty by snapping the thumb and finger at a distance of five feet from the telephone.

Fig. 2 shows another mode of inter-connection of two tubes. The stimulus from outside is introduced to the grid of the first tube through a transformer, as before, and the indicating instrument is again placed in the plate circuit of the first tube. The two plate circuits are in parallel with a common battery E, and the connections are such that the changes of P.D. between the anode and the filament of the first tube are imposed between the filament and grid of the second tube, and the changes of P.D. between the anode and filament of the second tube are imposed between the filament and grid of the first. In order to help to maintain the grids' advantageous potentials, grid leak resistances are connected as indicated.

The following numerical values are typical dimensions :—

E=80 volts
r_1=r_2=100,000 ohms.
e_1=e_2=40 volts.

The sensitiveness of this relay could be made greater than that of Fig. 1, when these large resistances are used.

The devices just described were the subject of a patent, numbered 10290/1918, taken out by the Admiralty, and the description is now published by permission.

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Review of Radio Literature

1. Abstracts of Articles.

72. A COMPARISON OF COILS AND AERIALS FOR RECEPTION. M. Abraham. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 259—269, August, 1919.)

The author investigates (1) the amount of energy which the coil or aerial can abstract from the electromagnetic wave, and (2) their relative susceptibility to atmospheric disturbance.

(1) It is known that the maximum amount of energy which an aerial can abstract from an undamped wave is independent of the constants of the aerial, *i.e.* it is the same for any aerial. To obtain this maximum it is necessary to adjust the ohmic resistance (aerial, detector, earth) to equality with the radiation resistance. The author shows that a coil or frame acts just like any other form of aerial and can abstract just as much energy if the ohmic resistance is correctly adjusted to the radiation resistance.

The radiation resistance R_r of a vertical coil is $\frac{4\omega^4 A^2}{3c^3}$, where $\omega = 2\pi f$, A = area $\times$ turns, and $c = 3 \times 10^{10}$, whereas the radiation resistance R_r' of an aerial is $\frac{4\omega^2 h^2}{3c}$, where h is the height. These values allow for the effect of the earth. Hence

$$\frac{R_r}{R_r'} = \frac{\omega^2 A^2}{c^2 h^2}.$$

This is usually a very small fraction; hence the total ohmic resistance should be made much smaller with the coil than with the aerial, and, of course, the resistance of the circuit apart from the detector should be made as small as possible. The author states that there is little prospect of the coil being made equivalent to the aerial in this respect.

(2) If an atmospheric disturbance produces a damped aperiodic electromagnetic field which can be represented at the receiving station by the formula

$$E = cH = a\varepsilon^{-rt}.$$

the equation for the coil is

$$\frac{d^2i}{dt^2} + 2\rho\frac{di}{dt} + \omega^2 i = \frac{A}{L}\cdot\frac{ar^2}{c}.\varepsilon^{-rt},$$

and that for the aerial

$$\frac{d^2i'}{dt^2} = 2\rho'\frac{di'}{dt} + \omega^2 i' = -\frac{h}{L'}\cdot ar\cdot\varepsilon^{-rt}.$$

The solution for the coil is

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$$i = B\left\{\varepsilon^{-rt} - \varepsilon^{-\rho t}\left(\cos mt + \frac{\rho - r}{m}\sin mt\right)\right\}$$

where

$$m = \sqrt{\omega^2 + \rho^2} \text{ and } B = \frac{aA}{cL}\cdot\frac{r^2}{m^2 + (r-\rho)^2}.$$

If the disturbance is much more damped than the receiver, ($r >> \rho$), the first term may be neglected. If, moreover, $\rho << \omega$, $m = \omega$, and

$$B = \frac{aA}{cL}\cdot\frac{r^2}{\omega^2 + r^2}.$$

and the energy supplied to the detector of resistance R_d is

$$Q = R_d\int_0^\infty i^2 dt = \frac{R_d}{4\rho}\cdot\frac{a^2A^2}{c^2L^2}\cdot\frac{r^4}{\omega^2(\omega^2 + r^2)}$$

Similarly, for the aerial,

$$Q' = \frac{R_d'}{4\rho'}\cdot\frac{a^2h^2}{L'^2}\cdot\frac{r^2}{\omega^2(\omega^2 + r^2)}.$$

The author adopts as a measure of the freedom from disturbance, the ratio q of the energy supplied to the detector in a given time T, by an undamped wave to which it is tuned, to that supplied by an aperiodic disturbance.

For the coil

$$q = \frac{T}{2\rho}\cdot\frac{\omega^4(\omega^2 + r^2)}{r^4}$$

and for the aerial

$$q' = \frac{T}{2\rho'}\cdot\frac{\omega^2(\omega^2 + r^2)}{r^2}.$$

These formulæ assume that the initial amplitude of the disturbing field is equal to the amplitude of the undamped field.

$$\frac{q}{q'} = \frac{\rho'}{\rho}\cdot\frac{\omega^2}{r^2}.$$

Hence the freedom from disturbance in either case is inversely proportional to the damping constant ($\rho = R/2L$) of the coil or aerial. Usually $\rho < \rho'$ and the aerial should therefore be superior to the coil in this respect. The coil is superior to the aerial if r is small compared with ω, that is if the aperiodic disturbance dies away slowly. This is generally the case.

[No reference is made to the directive action of the coil in excluding disturbances originating in directions normal to its plane.]

73. CALCULATION OF SELF-INDUCTANCE OF RECTANGULAR COILS. A. Esau. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 271—281, August, 1919.)

The present paper deals only with box-type coils, plane coils are reserved for a subsequent paper. Neumann's formula is used to calculate the mutual inductance between two parallel rectangles; the logarithmic terms are

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expanded and all terms beyond the squares neglected. The formula is then integrated over the whole n turns. This is an application of Strasser's method to rectangular coils.

The formula obtained for rectangular coils is very cumbersome and involves constants which must be obtained from Strasser's paper or from Rosa and Grover's paper in the *Bulletin of the Bureau of Standards*.

For square coils the formula is simplified and written $L = 8\,a\,n\,(S_1 + S_2)$, where a is the side of the square, n the number of turns, S_1 a function of a/ρ only, where ρ is the radius of the wire, and S_2 a function of a/g and of n, where g is the pitch of the turns. Tables and curves are given of these functions.

For maximum inductance with a given length of wire, the length l of the coil should be between $0{\cdot}4a$ and $0{\cdot}45a$.

For a given length of wire, the square coil has a greater inductance than a rectangle with unequal sides, but a round coil has 1·17 times the inductance of the square. Confirmatory experimental results are given.*

74. ON THE MULTI-SECTION QUENCHED GAP. M. Schuleikin and I. Freiman. (*Proceedings Institute Radio Engineers*, 7, pp. 417—425, August, 1919.)

The authors consider mathematically the relation between the breakdown voltage of a series of quenched gap section of the flat plate or "Telefunken" type, and that of a single section. Because of electric flux leakage from each plate to near-by plates and neighbouring conductors, the relation of direct proportionality does not hold. The breakdown voltage of a number of gaps of given length cannot be made to exceed a limiting value. Fig. 1 shows the results obtained plotted against the number of gaps in series for various "leakage" factors k. The factor $k = c/C$, where $C =$ the capacity between adjacent gap plates, and $c =$ the capacity of a plate to earth and to other neighbouring conductors, other than the next plate. The curve applies when one end of the series of gaps is earthed. If the mid-point of the transformer supplying the gaps is earthed, the maximum limiting voltages are double those given by the curves.

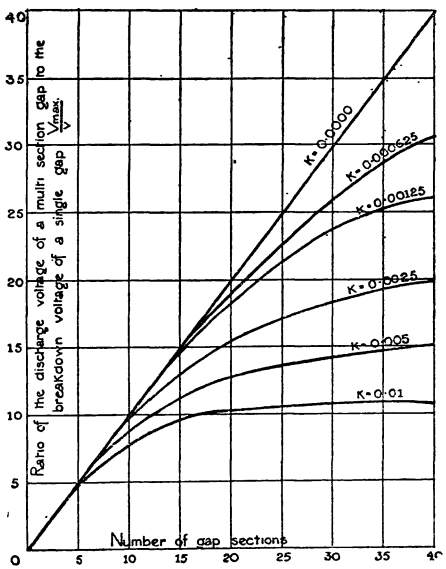

FIG. 1.

* See RADIO REVIEW, 1, pp. 124–126, where this paper is commented upon in the Editorial Article.

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75. SIMULTANEOUS SENDING AND RECEIVING. E. F. W. Alexanderson. (*Proceedings Institute Radio Engineers*, 7, pp. 363—390, August, 1919.)

Solutions for two distinct but similar problems are discussed in this paper, (1) the "Bridge" receiver, to provide a means for neutralising the overwhelming intensity of the transmitted signal so as to make the receiving

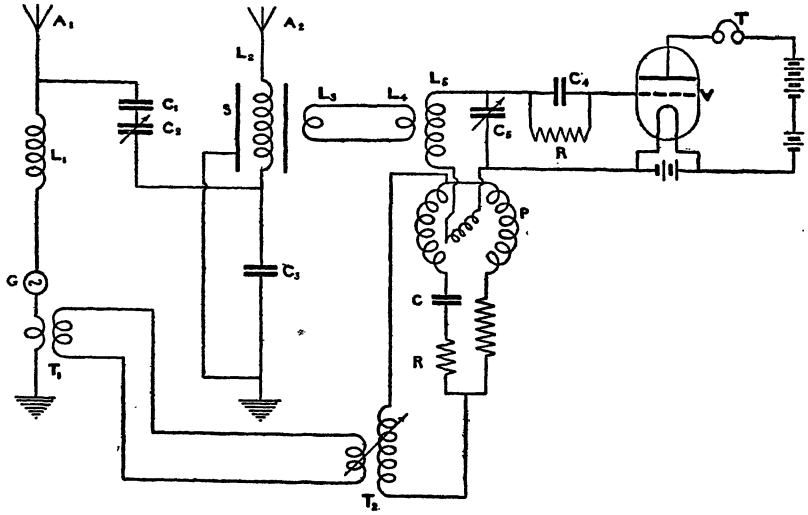

FIG. 2.

set sensitive to the distant signal; and (2) the "Barrage" receiver, to enable reception of a distant faint signal to be made, through heavy interference, not from the adjacent transmitter of the same station, but from other stations which are intentionally or accidentally jamming the receiver.

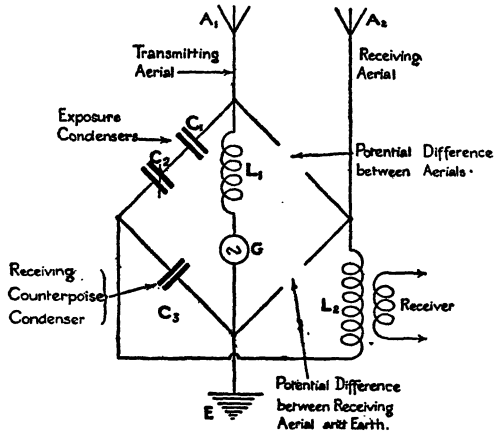

FIG. 3.

As an introduction to the Bridge receiver various other arrangements are considered for Duplex radiotelephony, *i.e.*, for radiotelephony in both directions without the necessity of repeatedly changing over the instruments from speaking to receiving during a conversation. In the first arrangement described, separate transmitting and receiving stations are employed,

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working on different wave lengths. The land line instrument is connected directly to the control amplifiers of the sending station; while the leads from the receiving station amplifiers are coupled (inductively) in series with this connection. Speech coming over the land line thus controls the transmitter; while incoming speech from the receiving station also operates the same control as well as the subscriber's land line telephone. Both halves of the conversation are thus repeated by both transmitters.

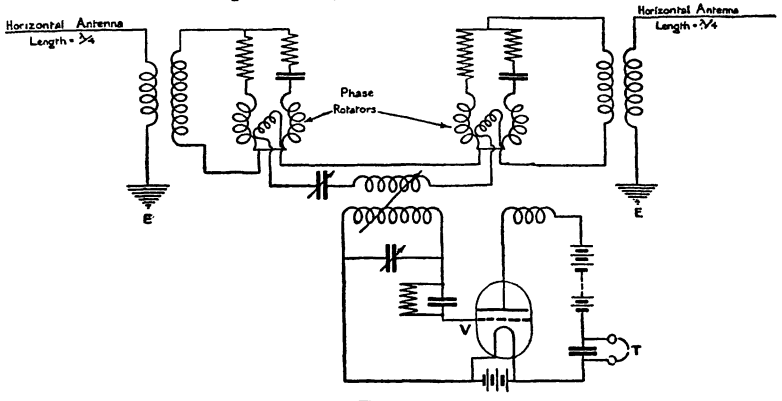

FIG. 4.

An analogous arrangement of two aerials at one station, with a system of inductive neutralisation of the interference between them, can also be used.

In the Bridge receiver proper an arrangement of capacitive neutralisation is adopted to eliminate the influence of the local transmitter upon the receiving instruments (Fig. 2). A_1 is the transmitting aerial; A_2 the receiving aerial, and G the source of oscillations. The coupling between the two aerials is effected through the "exposure" condensers C_1 C_2. The inductance in the receiving aerial circuit is screened electrostatically by the earthed sheath S, and is coupled through the untuned intermediate circuit L_3L_4 to an ordinary type of receiver L_5C_5V. The coupling coil L_3 is external to the earthed screen S. The "phase rotator" P, coupled to the transmitting aerial is used to

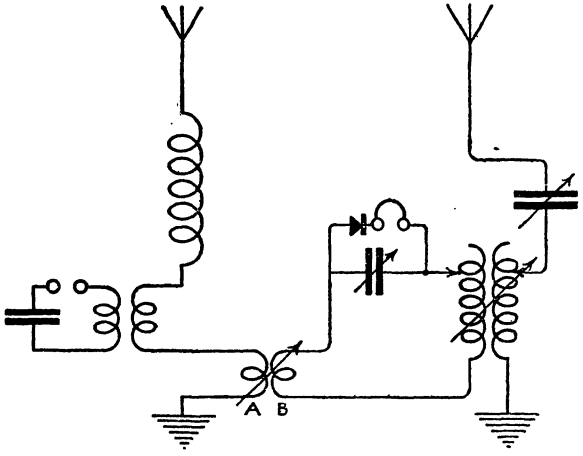

FIG. 5.

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balance out the direct interference occurring inside the station. Fig. 3 indicates the " bridge " nature of this arrangement.

The Barrage receiver is fundamentally a uni-directional receiver. Leading features of the design :—

(1) The antennæ should be aperiodic ;
(2) the balancing should be effected between the E.M.F.'s in the aperiodic aerials, *i.e.*, the phase shifting device should be aperiodic ;
(3) The two or more antennæ should be of the same character.

The barrage receiver takes advantage of the geographic phase displacement in the wave as it travels over the surface of the earth. One arrangement is indicated in Fig. 4.

	Bridge Receiver.	Detector Balance Method.
Local transmitter antenna current	7·0 amps.	18·5 amps.
Local transmitter transformer input . . .	0·8 kw.	5 kw.
Distant transmitter antenna current	10 amps.	4 amps.
Primary receiver current at balance	150 milliamps.	0·78 amps.
Primary receiver potential .	Approx. 10,000 volts	Approx. 1,000 volts.
Residual noise in phones .	Great	Small.
Quality of received signal .	Barely readable through interference.	Very good.

In the discussion on the paper W. H. PRIESS summarised the researches on similar lines carried out by the U.S. Navy Department during the war. Of these the most successful is the Detector Balance arrangement indicated in Fig. 5. The above table gives typical test results comparing this Detector Balance with the Bridge receiver.

The arrangement of Fig. 6 was stated to be a good means of balancing out atmospherics since the ratio of signal to static is different in the pure loop circuit to what it is in the circuit using the loop as an ordinary elevated aerial structure. Circuit B couples the loop circuit to the detector circuit F, and circuit C couples the aerial circuit D to the same detector circuit F.

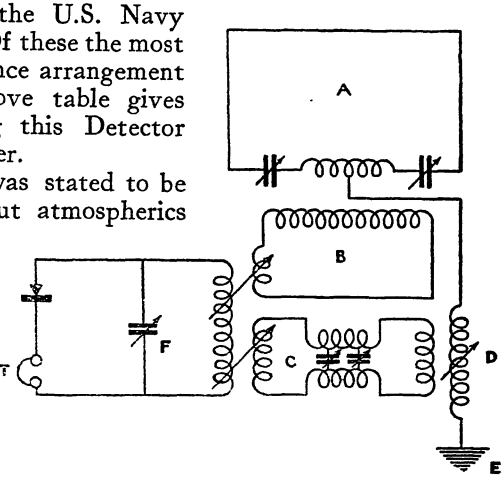

FIG. 6.

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76. A RADIOTELEPHONE TRANSMITTER. L. de Forest. (*French Patent* 492193. July 1st, 1919.)

The arrangement proposed is indicated in Fig. 7. The oscillating circuit C_1L_1 is joined between plate and grid of the valve. The transmitting

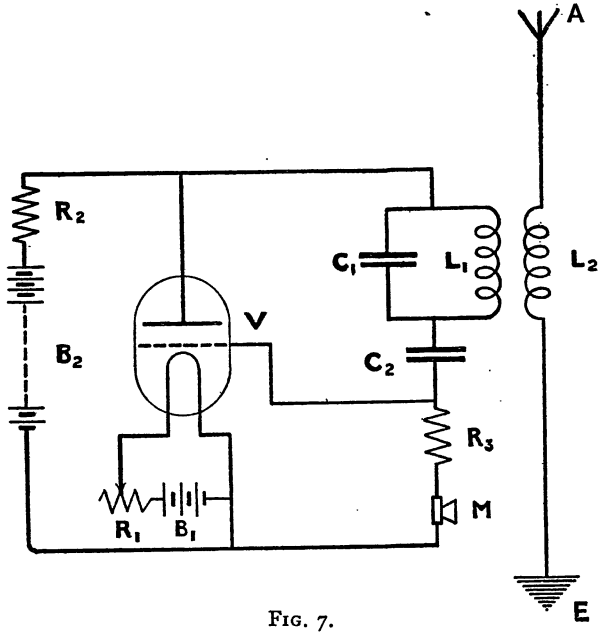

FIG. 7.

microphone M is joined in series with a resistance R_3 of 25 to 100 ohms between the grid and filament. C_2 is merely a stopping condenser to keep the H.T. from B_2 away from the grid.

77. THE INTERNAL ACTION OF AMPLIFYING VALVES. M. v. Laue. (*Annalen der Physik*, 59, pp. 465—492, August, 1919. *Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 243—259, Abstract.)

A mathematical investigation of the equipotential surfaces within three-electrode valves. Three types of valves are considered, (1) in which the anode and the control electrode are plane, the latter close to the filament but on the side remote from the anode; (2) in which the control electrode is a single wire parallel to the filament; (3) in which the anode is cylindrical and the control electrode consists of a number of wires parallel to and arranged uniformly around the filament. The problem is reduced to a two-dimensional one by assuming the filament, anode and grid to be infinitely long and the problem is further idealised by assuming:

1. that there is no space charge; and
2. that there is no potential drop along the filament.

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8. VACUUM TUBES IN THE ARMY. (*Wireless Age*, 6, p. 41, September, 1919.)

Details of various types of valves used by the U.S. Signal Corps during the war.

79. VACUUM TUBES. H. P. Donle. (*British Patent* 130965, August 8th, 1918. Not yet accepted, but open to inspection.)

Covers the arrangement described in RADIO REVIEW Abstract No. 17.

80. MEANS FOR DETERMINING THE DIRECTION OF A DISTANT SOURCE OF ELECTRO-MAGNETIC RADIATION. F. Adcock. (*British Patent* 130490, August, 1918. Patent accepted, August 7th, 1919.)

In D.F. stations the aerials are arranged with a vertical component to receive the radiation, and the horizontal connections arranged so that the effect of the radiation upon them is reduced to a minimum. Proposed connection arrangements for four vertical receiving aerials are shown in Fig. 8. In each case the earth lead for any aerial is taken across to the earth connection of the diametrically opposite aerial. L_{12} and L_{24} are the radiogoniometer coils.

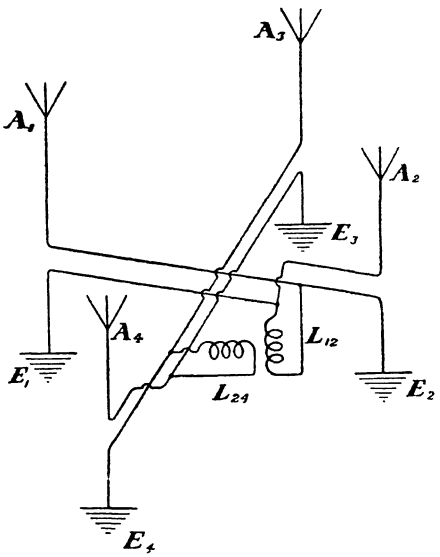

FIG. 8.

81. ÆTHER AND THE ABSOLUTE MECHANICS OF WAVE MOTION. G. Sagnac. (*Comptes Rendus*, 169, pp. 469—471, 529—531, September, 1919.)

82. THERMOPHONES OR HOT-WIRE RECEIVERS. (*Electrician*, 83, p. 242, September, 1919.)

Some further particulars are given *re* heater wires for thermophones. In support of the need for the use of very thin wires it is stated that $\frac{\text{watts expended in wire}}{\text{surface area of wire}} \propto d^3$ where d is the diameter of the wire; and that

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$\frac{\text{surface area}}{\text{cross section}} \propto \frac{1}{d}$. Curves of these relations are also given. The weight of these receivers is given as 0·25 to 0·5 oz.; and their resistance may be given any figure between 20 and 3,000 ohms according to the use for which the instrument is required.

83. ELECTRIC RELAYS. By M. Latour. (*British Patent* 127318, April, 1916.)

The amplification of high-frequency currents by vacuum valves is dealt with in this patent, and, in particular, the design of the iron-cored inter-valve transformers to secure the maximum amplification. A novel feature is the arrangements made for securing any desired static potential on the iron cores, metallic casing, and other parts of these transformers by making suitable connections between these parts and various points of the common anode battery.

84. IMPROVEMENTS RELATING TO AUDIONS, LAMP RELAYS, OR AMPLIFYING APPARATUS. M. Latour. (*British Patent* 129659, September, 1916. Patent accepted July 24th, 1919.)

An addition to Patent No. 127318. The static potential of the telephone headpiece is determined in addition to that of the core of the inter-valve transformers, by connecting one terminal of the telephone transformer to the telephone headpiece frame and to one of the terminals of the anode circuit battery.

85. DEVELOPMENT OF LOOP AERIAL FOR SUBMARINE RADIO COMMUNICATION. J. A. Willoughby and P. D. Lowell. (*Physical Review*, 14, pp. 193—194, August, 1919, Abstract of Paper read before the American Physical Society.)

In the close of 1917, in the course of experiments made with the object of developing apparatus for the detection of submarines, it was found that radio signals could be received by means of a loop, either in air or submerged in fresh water. The loop aerial arrangement, as finally perfected, consisted of two insulated wires earthed at the extreme ends of the hull of a submarine, carried over suitable supports to the bridge, and thence to the receiving and transmitting apparatus. Communication at sea can be carried on under all conditions more efficiently with such a loop than with ordinary elevated aerials. Also it does not interfere with submergence. With the submarine submerged any North American or European station could be received as distinctly as on the surface. To receive short waves it is necessary that the top of the loop should be near the surface of the water, whereas a wave of 10,000 metres length can be received with the top of the loop submerged 21 feet. Signals could be transmitted from the loop a distance of 10 or 12 miles with the submarine completely submerged. The range falls to two or three miles with the top of the loop 8 feet to 9 feet below the surface,

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using 952 metres wavelength. Submergence of the submarine during reception or transmission does not alter the wavelength. With the submarine on the surface a transmission range of at least 100 miles can be obtained with a 1-kw. spark set even under very stormy conditions. The loop can also be used as a direction finder.

86. IMPROVEMENTS IN ELECTRICAL RESISTANCES. S. R. Mullard. (*British Patent* 131057, April, 1918. Patent accepted, August 21st, 1919.)

A high resistance for use with valves consists of a thread of partially carbonised cellulose or the like embedded in insulating material such as paraffin wax, and enclosed in a fibre or ebonite tube.

87. THE EVOLUTION AND ABSORPTION OF GASES BY GLASS. D. Ullrey. (*Physical Review*, 14, p. 160, August, 1919, Abstract of Paper read before the American Physical Society.)

The absorption of various gases by glass and their subsequent evolution with vacuum heat treatment have been studied particularly with respect to the production and maintenance of high vacuum.

Conclusions: (1) The rates of evolution of the gases are in general different functions of the time at any temperature, and for a given baking period, are different functions of the temperature.

(2) There is a large variation in the quantity of gases evolved per $cm.^2$ from different samples of the same glass.

(3) Annealing in air at atmospheric pressure always lessens the quantity of gases evolved on subsequent vacuum heat treatment, although several months may elapse between the two processes.

(4) At a given temperature and pressure, glass is in equilibrium with a definite amount of water. Water vapour is evolved at high temperatures and re-absorbed when the temperature is lowered.

(5) Glass from which practically all absorbed gases have been removed by melting in vacuo subsequently re-absorbs gases from the atmosphere at room temperature.

(6) At temperatures up to the softening point, diffusion of gases of the atmosphere through glass does not take place.

2. Review of Books.

THE THERMIONIC VALVE AND ITS DEVELOPMENTS IN RADIO-TELEGRAPHY AND TELEPHONY. By J. A. Fleming, M.A., D.Sc., F.R.S. (London: *The Wireless Press, Ltd.* Pp. xv. + 280, Price, 15*s.* net.)

Any person concerned with matters technical who permits his fancy to wander over the arts which are his study and his occupation, finds himself at

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one time or another wondering what are the names of those to whom he is indebted for their first beginnings, and wanting to know something at least of how it all came about. These are idle thoughts, perhaps, for there is a quality about the work of the pioneer which never repeats itself as the subject becomes more widely exploited. Still, the processes of the application of scientific knowledge are not so obscure but that those who are in a position to break out into new fields of application in one art may expect to find practical utility in the study of the history of another. With original discovery, an obviously more delicate matter than application but not here in question, the deliberate study of method may, one must admit, end in defeating its own object.

The readers of this journal have to do with arts whose growth under the special stimulus of the last few years has been extensive and vigorous, and are therefore sure to feel in especial measure this interest in men and their methods, alike those entering upon their subject at some middle stage of its recent development, and those who find the full growth suddenly presented to their view.

Of the many who will take up Professor Fleming's book it will be those who are led by such stimulated historical curiosity who will be most likely to hold on to the end through all the distractions consequent on the utter thoroughness with which the author carries out his stated intention of vindicating his own personal case. They will also, after all is read, appreciate the full implications of the frank assignment to De Forest of the credit for introducing the third or grid electrode (p. 102).

This historical interest definitely predominates throughout the earlier chapters, and there are pages, for example p. 50 dealing with the bringing forth of the Fleming thermionic tube from its dusty cupboard, in which this interest will rise for some to a higher level, giving a sense of a really historic occasion.

But in this part of the book the technical exposition is continually interrupted or overlaid by the insertion of legal and similar extracts, to accommodate which an appendix is provided in addition. These extracts, however, embody numerous references, and may thus serve as an introduction to the " patent " aspect of the subject, and as some guide to such as expect to become involved therein, and even, it may be, to the Patent Office examiners to whom the author is so unkind on his opening page, always provided that their sense of duty leads them to read further. For some of these gentlemen, in this country at any rate, have been known to make a better success than Professor Fleming in combining a legal and technical exposition of this complex subject. They too will know better than the lay reader how to profit from the work of an author who is continually seen to be acting as expert witness in his own behalf.

In these first three historical chapters again, the technical reader must be content to repeat in his own person the errors and difficulties hitherto encountered by all who have entered unassisted on the study of valves. The latter will recognise certain familiar pitfalls, for instance, the overestimation of the importance of gas ionization, and the corresponding failure to appreciate the fundamental necessity of understanding what happens

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when the natural field between the electrodes is distorted by the appearance of free charges in space. Again on the electrodynamical side, it is of the first importance to see clearly how the energy set free in the anode circuit of a detector arrangement is actually made available, and such statements as that on p. 178, repeated from pp. 63 and 138, that " at each spark discharge at the transmitter a rectified train of oscillations, or a simple unidirectional *pulsating* flow of electricity passes *through the telephone*" are worrying in proportion to the thoughtfulness of the reader (the italics are the reviewer's). It is not until p. 181 in connection with Armstrong's work that any inkling is given of the functions of the shunting capacity, actual or virtual, in carrying the high-frequency pulsating component of the rectified train past the enormous impedance of the telephones. It is a pity that such recognised pitfalls, particularly in matters where to follow Professor Fleming's lead is but natural, should have been left so weakly guarded.

The division of aim from which the book suffers is far less pronounced in the later chapters, though by an unfortunate chance it is exemplified only too clearly in the closing paragraphs of the text. But from the technical aspect these later chapters improve progressively, and one is inclined to recommend those who seek up-to-date technical information clearly set out to begin by reading the last chapter of all. With the assistance of the excellent table of contents and the full index provided, they will readily pick up the earlier references to matters which this unconventional procedure may render obscure.

As regards the period of the war, here covered by a single additional chapter, the time for writing history has not yet come, and it is therefore not unexpected that few of the author's countrymen are specifically mentioned besides those responsible for the development of apparatus under the Marconi Company. For the same reason, perhaps, there is no mention of French work on valves and their circuits; nor among so many excellent photographic illustrations is there one of that instrument, the " French " valve, known later as the " R," which was used in hundreds of thousands by our troops, and which will in consequence be the one object called to the mind of the great majority of readers by the title of this book. To these the omission will appear inexcusable.

Official prohibition of the representation of so familiar an article is inconceivable, and indeed a sufficient description of it had in fact been approved for inclusion in Captain Turner's paper read to the Institution of Electrical Engineers in June of this year, a date prior to the latest appearing in this book, which is that of an American legal decision of July 7th, 1919.

It is a curious fact, and one that carries an unspoken commendation of De Forest's development work, that the characteristics of the " good " valve given on p. 167, which are those of the French valve alike with other valves of very different construction and appearance standardised and used in large numbers in this and other countries, are actually those usually found in the most reliable, though not the most sensitive of the audions. In the experimental development of the audion there must have been present either great skill or great luck. It was an instrument of notable possibilities,

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and its performances have provided a profitable occupation for many in unravelling the numerous problems they present. It seems in face of this that although the method of science may be more evident in Fleming, the spirit of discovery was more with De Forest.

On the question of nomenclature much might be said with little profit. The collected list of names for the "valve" given in the preface leaves one in truth breathless. To these the author proposes to add one more. As regards generality of application "thermion" is a slight improvement on "audion." It is euphonious, but, as is admitted, the fact that it is a coined word which has been used before in another sense is against it. However, in matters of taste the appeal to examples of proved merit is valid; the principles of such word-making have been imperishably enunciated by Faraday ("Experimental Researches," 397—403), on introducing what are now without exception established names in electro-chemistry and molecular physics. The study of "electrolytes" was well advanced when Faraday devised this and the allied words, but so well did he avoid names which might "at any time . . . lead to confusion or tend to support false views," that the "electrode," the "ion," and so forth are still without rivals.

Both the printing and illustration of the book are well carried out. Minor misprints have been observed on pp. 38, 105, 141. Something has gone badly wrong with the numbering of the paragraphs in Chapter I., where "7" occurs twice, on pp. 26 and 33, and "8" likewise on pp. 30 and 36.

In spite, however, of evidence of condensation, and of the large amount of information compressed into a comparatively small volume, the presentation of the subject in the later chapters is such, that one could wish that more of that sort had been written.

B. S. GOSSLING.

Correspondence.

THE OSCILLATING TRIODE.

TO THE EDITOR, THE "RADIO REVIEW."

SIR,—On p. 37 of your first issue, Dr. Whiddington is reported as giving the expression $\frac{1}{k}\left(\frac{L}{\rho} + RC\right)$ for the minimum value of M necessary to start oscillation, where k is defined as the "amplification factor." If, however, this factor is defined as the ratio of change of anode E.M.F. to change of grid E.M.F. (which seems to the writer to be the correct definition) then the expression given appears to be of wrong dimensions, and should be multiplied by ρ, giving

$$\frac{1}{k}(L + \rho RC).$$

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If, on the other hand, k is the ratio of anode current to grid E.M.F. change, *i.e.* a quantity having the dimensions of a conductance, then the expression given is, of course, correct.

Is it not preferable, however, to express the amplification as a simple ratio of E.M.F.'s ?

R. C. CLINKER.

Rugby, *November 1st*, 1919.

HARDENING AND SOFTENING OF IONIC TUBES.

TO THE EDITOR, THE "RADIO REVIEW."

SIR,—With reference to Dr. Eccles' interesting letter in your last number, it would appear that his explanation is more of the nature of a detailed consideration of what happens when a positive ion falls into the filament than of an explanation of the hardening and softening phenomena.

Dr. Eccles' suggestion differs somewhat from the generally accepted view in that he attributes the whole hardening process to the occlusion of gas in the filament. It has previously been supposed that the "clean up" was due to gas being driven into parts of the valve at lower temperatures than the filament. The question asked in the discussion at Bournemouth may well be repeated "how are they (*i.e.*, the positive ions) retained in the filament at 2,000° C. ?" At that temperature the average velocities are high and the average time that would elapse before a particular ion acquired a velocity sufficiently high to enable it to break away from the surface of the filament would surely be very short.

The whole phenomena of hardening and softening has been frequently observed when the currents through the valve have been less than 20 per cent. of the saturation current. Moreover, if a valve is hardened at a high voltage and is then run at a low voltage it is never observed to return to its original soft state. It softens to a smaller extent than the original hardening.

It may be observed that the electrons and ions are by no means confined to the space between the electrodes. Some proportion of them are flying round in external orbits and in following these paths some will strike the containing walls. Several cases are known in which the bombardment from these side orbits has led to sufficient local heating of the glass to cause cracking and puncturing of the walls.

It is believed that the valve manufacturers have information available that would throw a good deal of light on this question if it were carefully analysed.

C. L. FORTESCUE.
G. B. BRYAN.

Royal Naval College,
Greenwich,
November 4th, 1919.

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THE

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THE
RADIO REVIEW

VOL. I JANUARY, 1920 NO. 4

The Calculation of Loads in Guy Ropes for Masts or Towers.*

By C. T. G-HOOPER, A.M.I.Mech.E.

IN selecting a suitable guy rope for staying any structure such as a tower or mast, experience is a very valuable guide; but occasions may arise in which either conditions are so altered as to render past experience of doubtful value, or, the cost of the ropes being a considerable item, it may be desired to design them as economically as possible, that is, to supply ropes of no larger diameter than is consistent with the greatest loads they are likely to incur under working conditions.

For instance, the guy ropes staying the masts which support the aerial wire of a wireless telegraph station frequently have their continuity broken by means of insulators in order to lessen the risk of leakage to earth of the high-frequency current in the aerial. These insulators are necessarily of porcelain or other material of low tensile strength and consequently it is important that the load they will be called upon to bear should be known within fairly close limits.

The following are some simple rules, deduced from first principles, for ascertaining the tension likely to occur in any rope used for staying towers or masts. Six general cases have been taken, but the principles may be applied to almost any system of rope support.

The cases considered are :—

1. Mast stayed by ropes attached to top.
2. Mast stayed by ropes attached to intermediate point.
3. Mast stayed at two points, one being the top.

* Paper received June, 1919.

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4. Mast stayed at two points, neither being at the top.
5. Mast stayed at more than two points.
6. When guy ropes are duplicated and form an angle with each other.

In the first five cases it has been assumed that the heaviest load is taken by a rope (or ropes in cases 3, 4 and 5) when its vertical plane is the plane of the wind pressure acting, and that no support is given by the other ropes, they being assumed to be redundant for the time being.

The general assumption has also been made that the lower end of the tower or mast is fixed or *encastré* and that deflection is completely restrained there. In dealing with masts this is a condition which holds in practice, and it is therefore considered that the above assumption is justified and that it will introduce no appreciable error into the calculations.

The nomenclature adopted is as follows :—

A = Length of rope in plan in feet.
C = Constant for wind pressure = p lbs. per sq. foot.
d = Mean outside diameter of mast in feet.
H = Height of mast in feet.
L = Length of rope.
θ = Angle between rope and vertical.
T = Tension in rope in lbs.
W = Total load on mast due to wind = CdH lbs.
ω = Load per foot run due to wind = Cd lbs.

Other symbols as given in the text.

The results arrived at will hold good only for structures of circular cross-section which present an unbroken surface to the wind. The tensions induced in the guy ropes of a lattice tower or mast cannot be calculated directly from the formulæ given, as the wind loads, theoretically at least, will be less than those imposed on a plated or solid structure of the same dimensions. It is, however, a simple matter to apply the same method of calculation to all similar erections of whatever cross-section provided that the terms W and d are correctly dealt with.

CASE I.—MAST STAYED BY ROPES ATTACHED TO TOP. (Fig. 1.)

A mast is rarely guyed by means of ropes attached to its extreme end, but occasionally it has to be done in order that the

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ropes may avoid obstructions such as buildings, etc., and as it presents the simplest case it will be considered first.

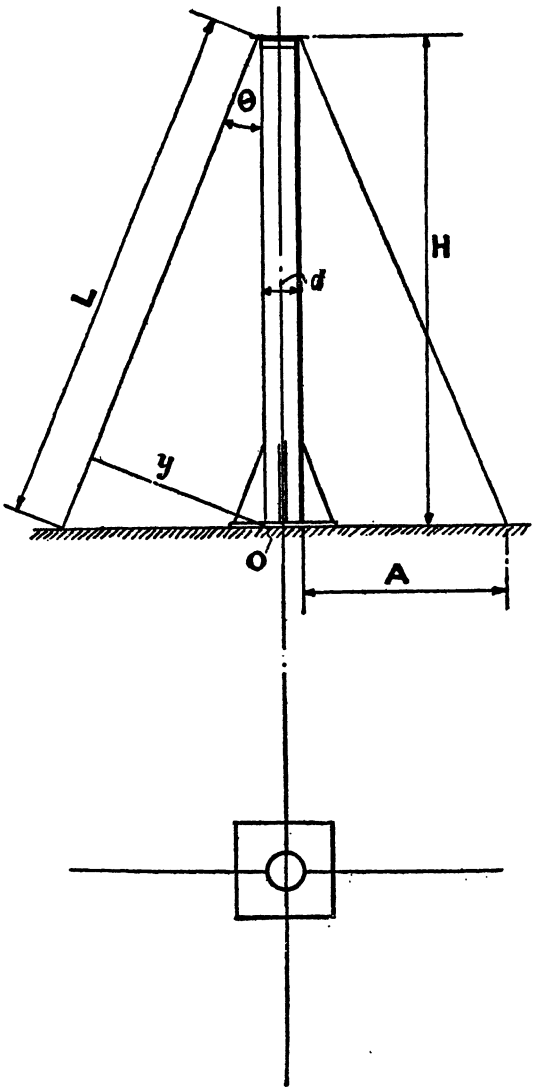

FIG. 1.

A mast supported as shown in Fig. 1 is under the same conditions as a cantilever with a uniformly distributed load and propped at its free end. It can be easily proved by equating the deflection at the end of a cantilever, due to a uniformly distributed load, to that due to a concentrated load at the same point, that the single force required to resist the deflection of the uniformly loaded cantilever is $\frac{3}{8}W$, where W is the total superimposed load. That is to say, the reaction at the propped end is $\frac{3W}{8}$ and consequently the reaction at the built-in end will be $\frac{5W}{8}$. In our case $W = CdH$, and at the built-in end there is also a fixing moment $= \frac{CdH^2}{8}$, and if we take moments about O, we get

$$T \cdot y = \frac{CdH^2}{2} - \frac{CdH^2}{8} = \frac{3CdH^2}{8}$$

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$$\therefore T = \frac{3CdH^2}{8y} \quad \text{but } y = A\cos\theta = \frac{AH}{L}$$

$$\therefore T = \frac{3CdHL}{8A} \quad \text{and as } L = \sqrt{H^2 + A^2}$$

$$T = \frac{3CdH\sqrt{H^2 + A^2}}{8A} \quad \ldots\ldots\ldots \quad (1)$$

When T has been multiplied by a factor of safety a suitable rope can be selected.

CASE 2.—MAST STAYED BY ROPES ATTACHED TO INTERMEDIATE POINT. (Fig. 2.)

Next considering a mast having a considerable portion of its length above the points to which the ropes are attached, such as

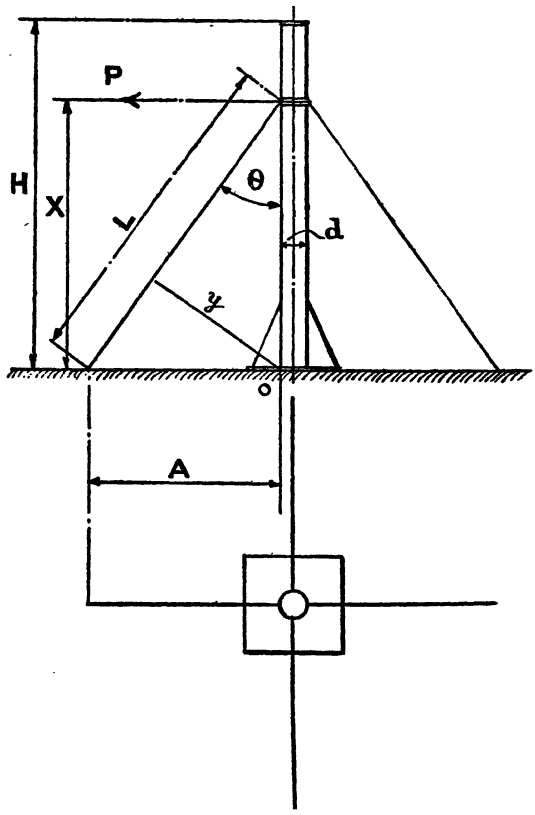

FIG. 2.

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TABLE I.

k	K	$P = KW$	P by moments.
1·0	0·375	0·375 W	0·500 W
0·9	0·445	0·445 W	0·555 W
0·8	0·537	0·537 W	0·625 W
0·7	0·659	0·659 W	0·714 W
0·6	0·825	0·825 W	0·833 W
0·5	1·062	1·062 W	1·000 W

that shown in Fig. 2. It will be seen that this is an example of a uniformly loaded cantilever propped at some point other than its free end.

If X the height of the point of attachment be expressed as a function of H, the total height, say as kH, then the value of the horizontal reaction P (which is the horizontal component of the tension T in the rope) may be calculated from the equation $\frac{Pk^3H^3}{3EI} = \frac{WH^3k^2}{24EI}(6 - 4k + k^2)$ (where E and I have their usual meaning in deflection formulæ), the left-hand side of the equation being the expression for the deflection of the mast at the point of attachment of the ropes under the concentrated load P, and the right-hand side representing the deflection at the same point due to the uniformly distributed load $\frac{W}{H}$ lbs. per foot run.

By cancelling we get

$$P = \frac{W}{8k}(6 - 4k + k^2) \text{ and making } \frac{6 - 4k + k^2}{8k} = K$$

$$P = WK = KCdH$$

In Table I., K has been calculated for all integer values of k between 0·5 and 1·0, and intermediate values may be estimated by taking the mean of the two nearest readings of k.

In order, therefore, to find the horizontal force P for any length of mast or tower stayed in the manner shown it is only necessary to obtain the ratio $k = \frac{X}{H}$ and against this ratio (expressed as a decimal) will be found the corresponding value of P in terms of W.

P must now be resolved in the direction of the rope, and from the triangle of forces,

$$T = \frac{P}{\sin\theta} = \frac{KW}{\sin\theta} = \frac{KCdH}{\sin\theta}$$

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But $\sin\theta = \frac{A}{L}$

$$\therefore\ T = \frac{KCdHL}{A} = \frac{KCdH\sqrt{X^2 + A^2}}{A} \quad . \quad . \quad . \quad . \quad (2)$$

If the mast had been considered as a beam uniformly loaded and simply supported at its base and at the point of attachment of the ropes, and the force P calculated by taking moments, the results would have been as shown in the column marked "P by moments" in Table I. and it will be observed that as the ratio $\frac{X}{H}$ decreases the values obtained thus and those calculated by the deflection formula more nearly agree.

Therefore for values of k between, say, 0·7 and 0·5, P could be calculated quite accurately enough by ignoring the "built-in" effect at the mast base, and taking moments, thus :—

$$P = \frac{WH}{2X} = \frac{CdH^2}{2X}, \text{ and}$$

$$T = \frac{CdH^2}{2X\sin\theta} = \frac{CdH^2L}{2AX} = \frac{CdH^2\sqrt{X^2+A^2}}{2AX} \quad . \quad . \quad . \quad (2a)$$

The expression for the tension T given above in (2) could also have been arrived at by the method adopted in the previous case, by taking moments about the point O, thus if $T \,.\, y$ is the moment of the tension about that point, and as the fixing moment at the base $= \frac{CdH^2}{2} - KCdH \,.\, X = CdH\left(\frac{H}{2} - KX\right)$,

then $T \,.\, y = \frac{CdH^2}{2} - CdH\left(\frac{H}{2} - KX\right)$

$= CdHKX$ and as $y = A\cos\theta = \frac{AX}{L}$

$T = \frac{KCdHL}{A}$ = the expression arrived at in (2).

CASE 3.—MAST STAYED AT TWO POINTS, ONE BEING AT THE TOP. (Fig. 3.)

If we next take the case of a mast stayed at two different points on its length as in Fig. 3, the method of treatment will depend on the relative positions in plan of ropes such as a and b.

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For instance, if there be some angle between *a* and *b* as in Fig. 3 (ii.) it may be assumed that if the wind pressure acts in the plane of the rope *a* no assistance will be given by *b* and *vice versâ*. Therefore the loads in these ropes can be estimated by means of the two previous formulæ—viz.:—*a* by means of formula (1) and *b* by formula (2). This is, of course not strictly correct, but will give results on the safe side.

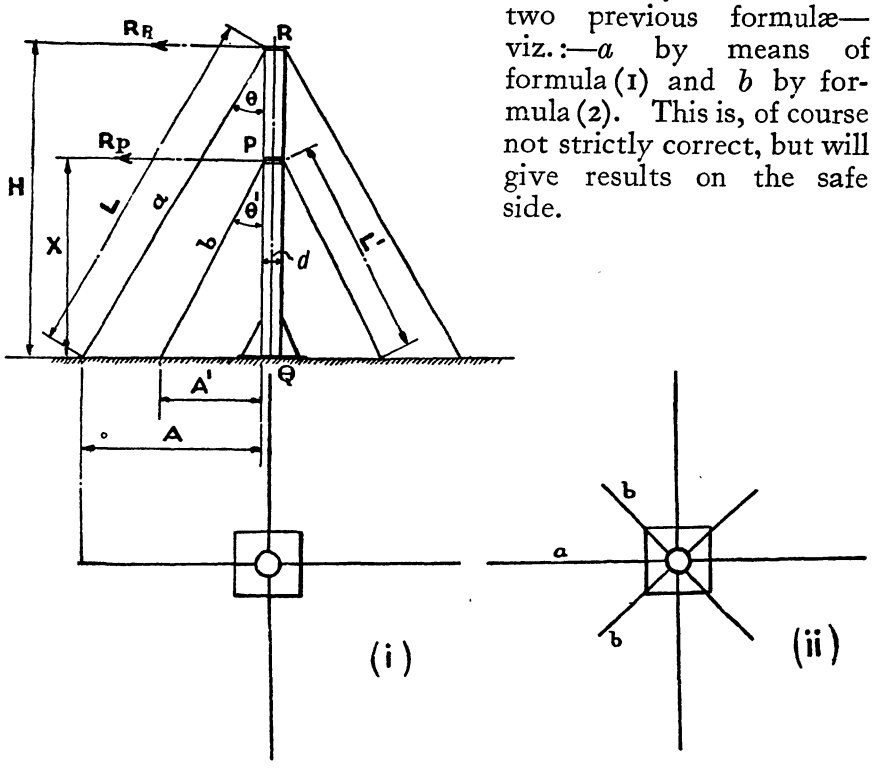

FIG. 3.

If, however, these two ropes are in the same vertical plane as in Fig. 3 (i.), it is obvious that deflection will be restrained at two points, by the tension T_A in the rope *a* of which R_R is the horizontal component, and the tension T_B in *b* of which R_P is the horizontal component. But it should be understood that unless the ropes *a* and *b* are both perfectly taut it will not be possible to estimate the reactions R_R and R_P accurately—so unless some means of tensioning these ropes be provided, such as rigging screws, it would be safer to design them with the two preceding formulæ (1) and (2), that is to say by ignoring the help given by *a* to *b* and *vice versâ*.

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Assuming, however, that means are provided for giving some slight initial tension to the ropes, the mast would then be under the same conditions as a continuous beam carrying a uniformly distributed load, having one end built in and two further supports, one being at the free end. There are three reactions to be determined, R_Q, R_P, R_R, and if

TABLE II.

k	K	K'	$R_P = KW$	$R_R = K'W$
0·95	1·898	− 1·381	1·898 W	− 1·381 W
0·9	1·075	− 0·539	1·075 W	− 0·539 W
0·8	0·683	− 0·105	0·683 W	− 0·105 W
0·7	0·577	+ 0·05	0·577 W	+ 0·050 W
0·6	0·551	+ 0·137	0·551 W	+ 0·137 W
0·5	0·571	+ 0·196	0·571 W	+ 0·196 W

M_Q = the bending moment at Q
M_P = the bending moment at P
M_R = the bending moment at R = 0.

The values of the reactions can be calculated from the general equation of the Theorem of Three Moments, namely *

$$M_Q X + 2M_P H + M_R(H - X) = \frac{W}{4H}\left\{X^3 + (H - X)^3\right\}$$

and, as one end is built in, we have the additional equation

$$2M_Q = \frac{WX^2}{4H} - M_P$$

If, as in the last case, we express X as a function of H, say kH, by substituting this in the above equations we arrive at the following general expressions, for the bending moments and reactions at the points of support, viz. :—

* This equation has been altered to suit the nomenclature used, and is more usually expressed as

$M_A l_1 + 2M_B(l_1 + l_2) + M_C l_2 - \frac{1}{4}(\omega_1 l_1^3 + \omega_2 l_2^3) = 0$, and in the above case :

$M_A = M_Q$
$M_B = M_P$
$M_C = M_R$
$l_1 = X$
$l_2 = H - X$
ω_1 and $\omega_2 = \omega = \frac{W}{H}$

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$$M_Q = \frac{WH}{4}\left(\frac{3k - k^2 - 1}{4 - k}\right)$$

$$M_P = \frac{WH}{4}\left(\frac{2 - 6k + 6k^2 - k^3}{4 - k}\right)$$

$$R_Q = \frac{W}{4}\left(\frac{k^2 - k^3 + 9k - 3}{4k - k^2}\right)$$

$$R_P = \frac{W}{4}\left(\frac{3-2k}{4k-5k^2+k^3}\right) = WK = CdHK \text{ where } K = \frac{3-2k}{16k-20k^2+4k^3}$$

$$R_R = \frac{W}{4}\left(\frac{6-12k+6k^2-k^3}{4-5k+k^2}\right) = WK' = CdHK'$$

$$\text{where } K' = \frac{6-12k+6k^2-k^3}{16-20k+4k^2}.$$

The two last reactions R_P and R_R are those with which we are chiefly concerned, and they have been calculated for values of k from 0·5 to 0·95 (see Table II.). It will be observed that between the points $k = 0{\cdot}7$ and $k = 0{\cdot}8$ the sign of the reaction R_R changes, that is to say, there is an intermediate point at which $R_R = 0$, and by equating the above expression for this reaction to zero this value of k will be found to be 0·74. Thus, when the value of k $\left(= \text{ratio } \frac{X}{H}\right)$ is between 0·5 and 0·74 the reactions at P and R will act in the same direction; but if k be greater than 0·74 these reactions will be in opposite directions.

If T_A and T_B are the tensions in ropes a and b respectively, then

$$T_A = \frac{R_R}{\sin\theta} = \frac{R_R L}{A} = \frac{K'CdHL}{A} = \frac{K'CdH\sqrt{H^2 + A^2}}{A} \quad . \quad . \quad (3)$$

$$T_B = \frac{R_P}{\sin\theta'} = \frac{R_P L'}{A'} = \frac{KCdH\sqrt{X^2 + A'^2}}{A'} \quad . \quad . \quad . \quad . \quad . \quad (3a)$$

Where θ', L', and A' have the meanings assigned in Fig. 3.

CASE 4.—MAST STAYED AT TWO POINTS, NEITHER BEING THE TOP. (Fig. 4.)

If, in the previous case, the rope a had been attached to a point some distance below the top of the mast, it would have presented a common example of the arrangement of guy ropes. As in the previous case, regarding the mast as a beam with one end built in and two further supports P and R, the reactions at these supports

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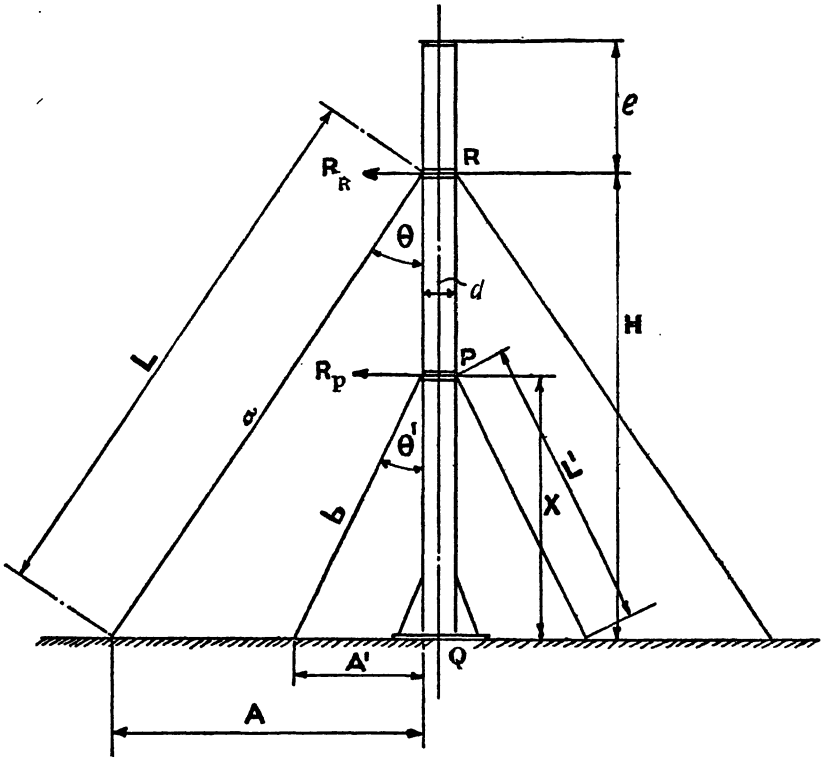

FIG. 4.

can be calculated as before from the equation of the Theorem of Three Moments :—

$M_Q X + 2M_P H + M_R(H - X) = \frac{\omega}{4}\left\{X^3 + (H - X)^3\right\}$ and the equations due to the particular end conditions, viz. :—

$$2M_Q = \frac{\omega X^2}{4} - M_P \text{ for the end } encastré, \text{ and}$$

$$M_R = \frac{\omega e^2}{2} \text{ for the overhanging end.}$$

The prefix "M" denoting "bending moment at" and "R" denoting "reaction at" as before.

The bending moment M_P at the point P can be expressed generally :—

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$$M_P = \frac{\omega}{16 - 4X}(2H^3 - 6H^2X - 6HX - X^3 - 4e^2H + 4e^2X)$$

and the remaining bending moments and reactions can be expressed in terms of M_P thus :—

$$M_Q = \frac{\omega X^2}{8} - \frac{M_P}{2}$$

$$R_Q = \frac{5\omega X}{8} - \frac{3M_P}{2}$$

$$R_P = \frac{\omega X(X^2 - 4e^2 - 5XH + 4H^2) - 4M_P(X - 3H)}{8X(H - X)}$$

$$R_R = \frac{\frac{\omega}{2}(H - X + e)^2 - M_P}{H - X} \text{ or } \omega(H + e) - R_Q - R_P.$$

These expressions for R_Q, R_P and R_R have been obtained by taking moments about the points P, R and the free end respectively, the corresponding equations being,

$$-R_Q X + \frac{\omega X^2}{2} + M_Q = M_P$$

$$-R_P(H - X) - R_Q H + \frac{\omega H^2}{2} + M_Q = M_R$$

$$-R_R \cdot e - R_P(H - X + e) - R_Q(H + e) + \frac{\omega(H + e)^2}{2} + M_Q = 0.$$

R_P and R_R are the reactions we require, and having obtained them the tensions in the ropes a and b will be given by

$$T_A = \frac{R_R}{\sin\theta} = \frac{R_R L}{A} = \frac{R_R\sqrt{H^2 + A^2}}{A} \quad \ldots\ldots\ldots \quad (4)$$

$$T_B = \frac{R_P}{\sin\theta'} = \frac{R_P L'}{A'} = \frac{R_P\sqrt{X^2 + A'^2}}{A'} \quad \ldots\ldots\ldots \quad (4a)$$

CASE 5.—MAST STAYED AT MORE THAN TWO POINTS.

A mast stayed at any number of places on its length can be dealt with by the method adopted in the last two cases, that is, by the Theorem of Three Moments. It is simply the case of finding the reactions at the points of attachment of the ropes. Having obtained these, they are then resolved in the direction of the rope, as in all the previous examples.

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CASE 6.—WHEN GUY ROPES ARE DUPLICATED AND FORM AN ANGLE WITH EACH OTHER. (Fig. 5.)

All the previous cases considered have been those in which a single rope has been considered as supplying the reaction at the point of attachment to the mast. In practice, however, two ropes are sometimes used, both being fixed to a common point on the mast, as shown in Fig. 5.

If at this point, R is the reaction as calculated by means of any of the formulæ given in the text for P, R_P, or R_R, the tension in each of the two ropes will be given by

$$T = \frac{R\sqrt{X^2 + A^2 + f^2}}{2A}$$

where f has the meaning given in Fig. 5.

This formula is obtained by resolving the reaction R in the two directions, and it may be noted that the factor $\sqrt{X^2 + A^2 + f^2}$ is the true length of the rope.

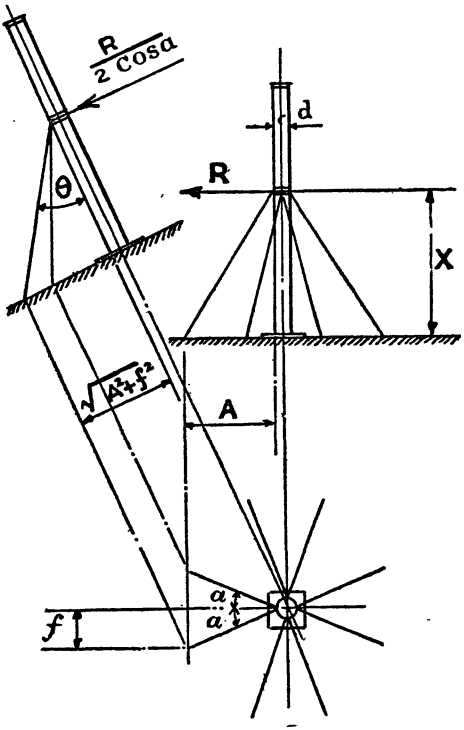

FIG. 5.

In calculating the tension by any of the preceding formulæ it should be remembered that the result will only be correct when the whole length of the mast is exposed to the wind, and when the point of attachment of the ropes to the ground is in the same horizontal plane as the base of the mast.

Should the latter be resting on a foundation Z feet high, above the horizontal level at which the guy ropes are anchored, as in Fig. 6a ; or if the point of anchorage be Z feet below the level of the mast base as in Fig. 6b, it will be necessary to substitute—

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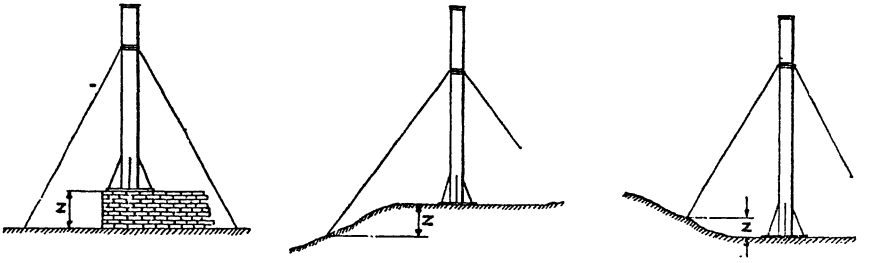
$\frac{AH}{H+Z}$ for A in the formulæ (1), (3) and (4).

$\frac{AX}{X+Z}$ for A in the formulæ (2) and (2a), and

$\frac{A'X}{X+Z}$ for A' in the formulæ (3a) and (4a).



(a) (b) (c)

FIG. 6.

If, on the other hand, the point of anchorage is Z feet above the base of the mast, as in Fig. 6c, the expressions $\frac{AH}{H-Z}$, $\frac{AX}{X-Z}$ and $\frac{A'X}{X-Z}$ must be used in place of A and A' in the respective formulæ.

A Variable Liquid Resistance.

By F. W. JORDAN, B.Sc.

IN many experiments in electrical laboratories a smoothly variable resistance of fairly large value is frequently required. Such resistances are becoming very desirable in high-frequency work, especially in connection with cascade amplifiers.

The accompanying diagram describes very fully the construction of a variable resistance which has proved very useful in certain researches with triode valves. It consists of a glass U-tube with large open ends which act as reservoirs, solid glass rods sliding in the limbs of the U, and two electrodes. Each of the electrodes is formed by winding bare copper wire into an annulus which fits inside one of the large open ends of the U. The electrodes are fixed in position, and when in use the glass tube is filled with dilute copper sulphate solution.

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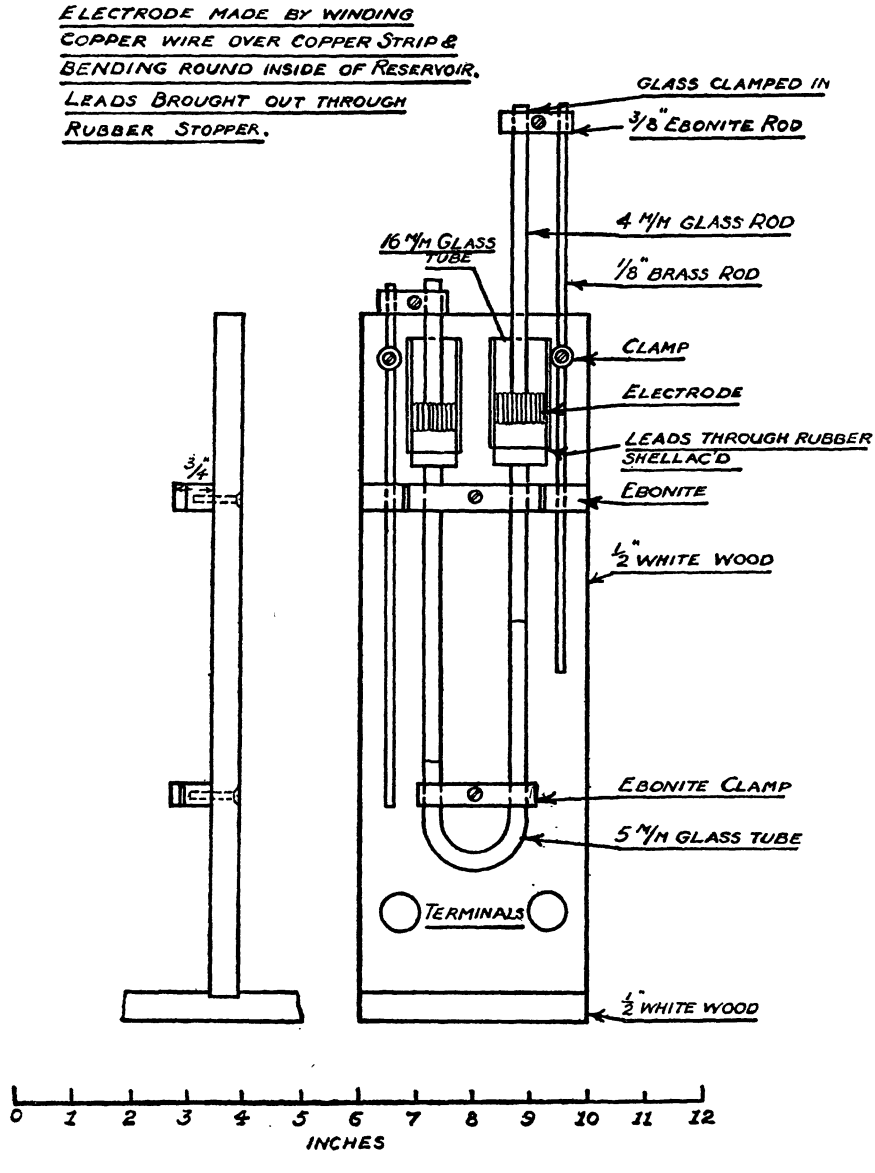
The resistance between the electrodes is varied by sliding more or less of the vertical solid glass rods into the tube. The glass rods are held in position by clamping the brass rods which support them. This construction has the advantage of fixed electrodes, free from soldered joints.


ELECTRODE MADE BY WINDING COPPER WIRE OVER COPPER STRIP & BENDING ROUND INSIDE OF RESERVOIR. LEADS BROUGHT OUT THROUGH RUBBER STOPPER.
GLASS CLAMPED IN
3/8" EBONITE ROD
4 M/M GLASS ROD
16 M/M GLASS TUBE
1/8" BRASS ROD
CLAMP
ELECTRODE
LEADS THROUGH RUBBER SHELLAC'D
3/4"
EBONITE
1/2" WHITE WOOD
EBONITE CLAMP
5 M/M GLASS TUBE
TERMINALS
1/2" WHITE WOOD
0 1 2 3 4 5 6 7 8 9 10 11 12
INCHES

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The Relative Advantages of Elevated Antennæ, Loop Aerials, and Underground Wires for the Reception of Radio-Signals.

By THE EDITOR.

ONE of the results of the development of the thermionic amplifier has been the greatly increased employment of relatively small loops as receiving aerials. This is a return to the earliest method on record for detecting electromagnetic waves, since Hertz used a loop receiving aerial in his classic experiments. The detectors now in use, however, are of a sensitiveness undreamt of even ten years ago. There are at the present time three types of aerials in use, viz., the elevated antenna, the closed loop, and the horizontal underground wire, and a number of papers have been published during the last few months dealing with various aspects of the relative advantages of these various methods of detecting radio-signals. Apart from mechanical, financial, or military considerations the discussion must centre round two points, firstly, their sensitiveness and secondly their freedom from atmospheric disturbance. To any one acquainted with the delay and inconvenience caused at present in long distance transmission by "atmospherics" it will not be surprising if more stress is laid on the latter consideration. If an aerial can be employed of a type which discriminates to an increased degree between the desired signal and the atmospheric disturbance, one is prepared to sacrifice much in sensitiveness, since, if necessary, the signal can be amplified up to the requisite strength. In many cases the signal is quite audible but unreadable because of "atmospherics." Both underground wires and loops appear to be superior to the elevated antenna in this discriminating property. This is due to a large extent to the directiveness of the former, since they do not pick up atmospherics at their full intensity unless these come in the same direction as the signal. There seems to be no doubt, however, that the discrimination goes further than this and that both the loop and the underground wire

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give a larger ratio of signal to static—to use the American phrase —than does the elevated antenna, even when the signal and static come from the same point of the compass.

The electromagnetic waves emanating from a transmitting station and travelling over the earth's surface are associated with radial alternating currents in the upper layers of the earth's crust, which are poor conductors especially the surface layer. If a long copper cable be buried in a direction radial to the transmitting station, this alternating current will flow through it in preference to the surrounding soil, especially if several cables are arranged T-shape or fan-shape, coming together at the receiving station and then spreading out again. In this way the current which would otherwise flow over a considerable area is concentrated on the receiver. The cables should preferably be buried below the very dry upper layer, the better to collect the current. If well insulated cables are used, the system can be sharply tuned ; there is then no conducting connection between the copper core and the earth, but the insulation of the cable acts as the dielectric of a condenser. The velocity of an electromagnetic wave along such a cable is less than the velocity through space in the ratio of the square root of the specific inductive capacity of the dielectric. Its wavelength for a given frequency will be correspondingly reduced. If the total length of the cable is a half the wavelength or one and a half wavelengths, it will be in resonance to the received wave with a current maximum at the centre. Many interesting experiments with buried insulated wires are described by A. H. Taylor in the August number of the *Proceedings of the Institute of Radio Engineers*,* and striking examples given of the reception of distant stations when " atmospherics " made this impossible on ordinary antennæ. There is, however, room for much further research along the lines indicated above.

If it be granted that atmospheric disturbances are propagated by electromagnetic waves of the same general character as the signal waves, they also will be associated with earth currents and if the direction of propagation is the same, any discrimination on the part of the underground receiving system must be due to the different characteristics of the two waves as regards frequency and decrement. Any difference between the underground wires and an antenna in their discriminating power must be due, however,

* RADIO REVIEW, Abstract No. 149.

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to their different characteristics when regarded as oscillatory circuits. The same is true with respect to coil or loop aerials.

Two papers of interest have recently been published dealing with the loop aerial, one by Max Abraham of the Telefunken Company (until recently Professor at Strassburg) treating the problem from a purely academic point of view, and the other by Captain Blatterman of the U.S. Signal Corps of a more practical nature. It was known that the maximum amount of energy that a given type of antenna can abstract from an electromagnetic wave and deliver to the detector is theoretically independent of its height and is dependent only on the amplitude of the wave and on the wavelength. The condition to be fulfilled to obtain this maximum is that, of the three resistances—viz. (1) the radiation resistance, (2) the loss resistance due to wires, earth, imperfect dielectrics, etc., and (3) the useful resistance that is, the detector resistance reduced to its equivalent value in the aerial—the second should be negligible and the third should be equal to the first. The radiation resistance of an antenna being proportional to the square of the height, it follows that if the detector resistance in a 10-foot antenna is reduced to a hundredth part of that in a 100-foot antenna, and if moreover the loss resistance is reduced in the same proportion, both of these aerials will, if tuned to the same electromagnetic wave, collect from the ether and deliver to the detector the same amount of energy. Now Abraham shows that a loop is able to supply exactly the same amount of energy to its detector under the same conditions, but that on account of its small radiation resistance, the conditions are practically impossible to attain since it is impossible to reduce the loss resistance in the necessary proportion. It is useful, however, to bear this fact in mind when designing loops and their detecting arrangements.

To make a circuit respond readily to impulses to which it is tuned, and but slightly to aperiodic or low-frequency impulses it is necessary to reduce the damping of the circuit as much as possible. Abraham comes to the conclusion that the superiority of the loop is largely due to the fact that its damping ratio $R/2L$ is usually smaller than in an elevated antenna. A further reason is to be found, however, in the fact that to waves of a greater length than those of the signals or to aperiodic disturbances of small decrement, the phase angle represented by the distance between the two vertical sides of the loop is relatively less and that therefore for a given electromotive force induced in each side, the resultant

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electromotive force in the whole coil is smaller. Since atmospheric disturbances always appear to have much longer wavelengths than those employed in telegraphy this may be an important factor in reducing their effect on a loop. The paper by Captain Blatterman records and analyses a great amount of valuable experimental work in comparing the results obtained with loops of various sizes and numbers of turns. Since all loops are equally effective if their resistances are suitably reduced and their detectors properly adjusted, it follows that the choice of a proper design is largely a question of the ratio of the three resistances enumerated above. Blatterman gives much valuable data with respect to the resistances actually found in loops of various designs at different frequencies.

The Design of Multiple-Stage Amplifiers Using Three Electrode Thermionic Valves.

By PROFESSOR C. L. FORTESCUE.

(Abstract of paper read before the Wireless Section of the Institution of Electrical Engineers on Wednesday, November 19th, 1919.)

THE methods given in this paper were developed in the course of working out the design of valve amplifiers for use for naval wireless telegraphy purposes, and permission to publish this paper has been specially given by the Admiralty. The author is indebted to various co-workers for numerous suggestions which led, finally, to the form given. A vast amount of experimental work on the subject was carried out at H.M. Signal School, Portsmouth, by Lieutenant J. K. Catterson-Smith, R.N.V.R., and Lieutenant W. A. Appleton, R.N.V.R. Many suggestions were made at different times by Mr. H. A. Madge and Mr. Gossling of the Signal School, Portsmouth, and by Captain H. J. Round of the Marconi Company.

The paper is divided into four main sections :—

(A) Description.
(B) Reaction Effects and the Tendency for Alternating Currents to be Maintained in the Circuits connected to the Tubes.
(C) Other Limitations to the Effective Amplification.
(D) Theoretical Treatment.

In the first section general descriptions are given of four main arrangements :—

(1) The simple case of a single valve used as a resistance amplifier ;
(2) The use of tuned circuits instead of resistances ;
(3) Selective and non-selective amplifying ; and
(4) Cascade amplifying.

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The action of an amplifying system, electrical, mechanical, and otherwise is strongly affected by any transfer of energy back from the output end of the system to the input end, by any form of return coupling. If this coupling is such that the changes at the input end are accentuated it follows that changes of a given amplitude can be maintained by a smaller power supply. In the extreme case the coupling may be strong enough to do more than maintain the changes at the input end. The system is then unstable and oscillations are generally set up and maintained. If the coupling between the ends of the system tends to oppose the changes at the input end the effective amplification is reduced. The return coupling may be a capacity coupling, a mutual inductance, or a combination of the two or resistance coupling may also be employed in conjunction with either capacity or inductive coupling. Capacity coupling is always present to some extent. In practice it is desirable to reduce this unavoidable coupling as much as possible.

The tendency towards the generation of oscillations may in practice be controlled by varying the grid voltage of the valves. By making the grid more positive, the grid damping is increased and the valve becomes more stable.

There are several limitations to the effective amplification of the set. Amongst these may be mentioned :—

(1) External interference of the same nature as the P.D. variation to be amplified.
(2) Minute irregularities in the behaviour of the valves themselves.
(3) Constancy of the batteries used ; bad contacts, etc.

The theoretical treatment of the problem is based on the slopes of the straight parts of the four characteristic curves of the valve, viz :—

$$k_1 = \frac{di}{dv'}\,;\quad k_2 = \frac{di}{dv}\,;\quad k_3 = \frac{di'}{dv'}\,;\quad k_4 = \frac{di'}{dv}.$$

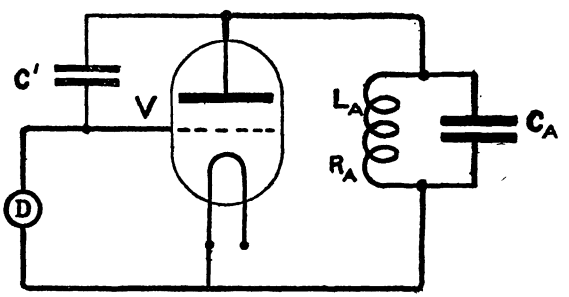

FIG. 1.

where v = anode voltage; v' = grid voltage; i = anode current, and i' = grid current; and the assumption is made that the static characteristic of the valve is followed at high frequencies.

For the complete case for a single valve (see Fig. 1) it is shown that the amplification

$$\frac{\delta v}{\delta v'} = \phi = -\frac{k_1 - j\omega C'}{j\omega(C_A + C') + k_2 + 1/(R_A + j\omega L_A)}$$

where C', C_A, L_A, and R_A have the meanings shown in the Fig. From

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this equation it is evident that the internal capacity of the valve (indicated by C') affects both the resonant frequency and the sharpness of the resonance. The sharpness of resonance depends also in the relative values of the terms $1/(\omega L_A)$ and $\omega(C_A + C')$ as compared with k_2. If they are small then resonance is not marked. This is the prevailing condition when C_A is the self-capacity only of the winding L_A.

The exact conditions for resonance are given by

$$(C_A + C') = L_A/(R_A^2 + \omega^2 L_A^2)$$

and under these conditions the maximum voltage step-up is

$$\frac{k_1 - j\omega C'}{k_2 + R_A/(R_A^2 + \omega^2 L_A^2)}.$$

The effect of the valve capacity is to throw an extra load upon the input circuit—represented by the alternator D in Fig. 1. This leads to additional damping of that circuit, and shows that there will be no tendency to generate oscillations *at the resonant frequency*. At other frequencies this will not necessarily be the case.

When dealing with more than one valve, it is assumed that the valve characteristics are identical and that the circuits are identical, and equations are developed similar to the above for the amplification and for the power taken, drawn from that circuit, for the cases of two and three valves while general equations are also indicated for any number of valves.

Professor G. W. O. HOWE opened the discussion, and suggested that the difference between the static and dynamic characteristics mentioned in the paper, might arise through changes in the temperature of the filament brought about by changes in the anode current. When taking the static curve the filament temperature would be able to follow changes in the anode current, but with the valve oscillating it would not be able to do so.

Mr. L. B. TURNER described an arrangement of two valves with resistance coupling only, making use of the retroactive coupling to secure amplification. This arrangement he termed a "Kallirotron." He claimed to have maintained a voltage amplification of 2,000 using only two valves.

Mr. CATTERSON-SMITH described the difference between the amplification obtainable with resistance-coupled amplifiers and that with transformer-coupled ones. With the former the amplification increased steadily with the wavelength, whereas with the latter there was usually a sharp maximum of amplification at some particular wavelength. Transformer coupling was therefore best for short wavelengths. He also described colloidal platinum and carbonised cellulose resistances for use with multi-vale amplifiers.

Captain H. J. ROUND spoke about "valve-noises," and pointed out that they were least troublesome with short wavelengths. He had obtained a voltage magnification of $0{\cdot}5 \times 10^6$ using twenty-two valves in cascade on short wavelengths without trouble from valve noises.

Major ERSKINE MURRAY referred to the difference between the static and dynamic characteristics obtained with power valves as used in the R.A.F.; and Captain SLEE dealt with the noises in amplifiers arising

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through bad contacts and irregularities in the H.T. batteries, while Mr. SCOTT-TAGGART and Dr. W. H. ECCLES also contributed a few remarks.

Mr. B. S. GOSSLING quoted some calculations he had made relative to valve noises being due to the deposition of positive ions from the residual gas upon the valve filaments and showed that to coat the filament with a single layer only of ions would require about 100 seconds. This therefore could not be the cause of the noises, although this time agreed closely with the rate of slow variation of anode current noticed when a valve was first switched on to circuit.

Professor FORTESCUE reserved the bulk of his reply to the discussion for communication to the Institution Journal.

A System for the Reception of Continuous Waves.

By J. SCOTT-TAGGART.

(Abstract of paper read before the Wireless Society of London on November 26th, 1919.)

THE arrangement described is of interest largely because it solves in one way the problem of producing a continuous-wave wireless receiving circuit capable of "standby" and "tuned" adjustment combining ease of manipulation and high selectivity. In addition the circuits may be adjusted so as to reduce radiation to a negligible value. The complete arrangement was designed by the author, and used for certain special artillery communications during 1917 and 1918. As evidenced by reports it proved of exceptional value in battle and overcame the difficulty, previously experienced, of interference by neighbouring "spark" stations.

The arrangement may be divided into three essential circuits: (A), (B), and (C). (Fig. 1.) The circuit (B) is of the usual type. An aperiodic retroactor coil L_2 is variably coupled to a variable inductance L_1, for the purpose of causing the circuit (B) to generate oscillations if required. The frequency of these oscillations is determined chiefly by the value of the condenser C_1. The filament of the vacuum tube V_1 is heated by a 6-volt accumulator B_1 through a rheostat R_2 of about 5 ohms resistance. The plate battery B_2' of about 60 volts and the primary T_1 of a step-up transformer T_1 T_2 are connected as shown, a fixed condenser C_3 of about 0·0003 mfd. being connected across B_2' and T_1 to by-pass the high-frequency component of the plate current of V_1.

The circuit (A) is exactly the same as (B) except that no aerial or earth connection is made, and the filament of V_2 is heated from the common battery B_1. A double-throw change-over switch S enables the receiver (C) to be connected to either T_4 or T_2. This circuit (C) comprises a "note-magnifier" V_3 V_4 and the receiving telephones T.

The circuit (A) is placed near to the circuit (B) and their distance apart should preferably be variable. For eliminating interference (A) may be placed as much as six feet away from (B) although one to two feet is more

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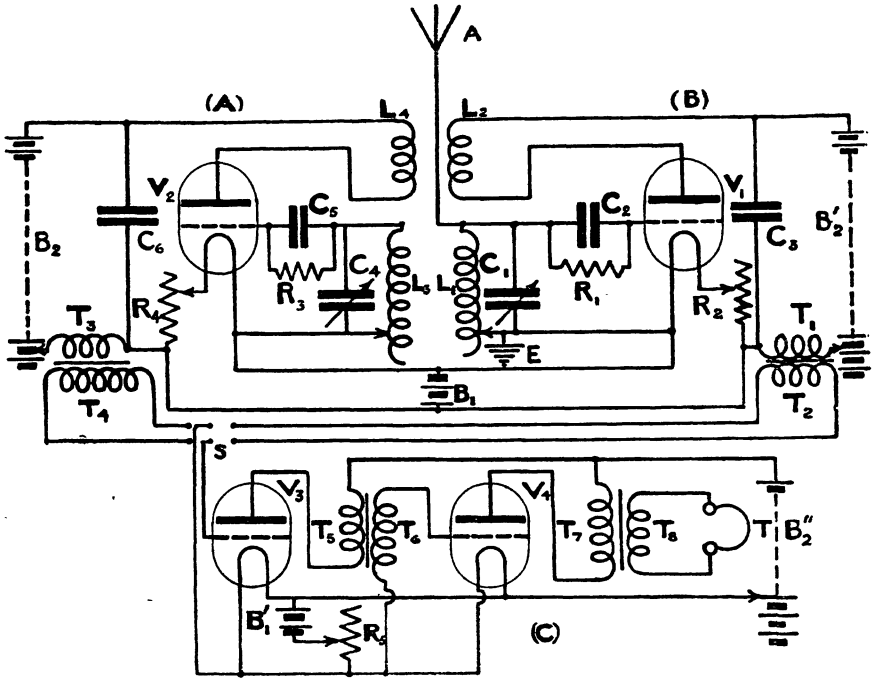

FIG. 1.

usual. For listening in on the " standby " position the circuit (B) is used as a self-heterodyne, and in this connection it should be noted that for a beat note to be produced, the aerial circuit must be slightly mistuned. The incoming waves are, therefore, forced into the aerial circuit in spite of the fact that the latter is out of resonance, so that there is a consequent loss in signal strength. An important disadvantage of the self-heterodyne circuit is that it radiates while receiving and may give rise to interference at other stations.

The disadvantage of excessive jamming may be largely overcome by tuning the oscillating (B) circuit to the silent point, decreasing the coupling between L_1 and L_2 or decreasing the filament current of V_1 so as to prevent V_1 from oscillating, and then switching S over to the left and re-tuning on the (A) circuit which is then made to oscillate. Owing to the very loose coupling between L_1 and L_3 spark signals suffer in amplitude to a much greater extent than C.W. signals, while the energy radiated from the aerial is considerably weakened. A further development which leads to much louder signals is to adjust the (B) circuit to the pre-oscillatory or subgenerative condition immediately preceding self-oscillation, by increasing the coupling of the retroactor coil L_2, or the magnitude of the filament current, which latter adjustment is preferable, the incoming continuous waves are now retro-

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actively amplified, with the result that louder signals are obtained in the telephones T.

The ratio between the amplitude of the local and incoming oscillations is of great importance. Suppose that the amplitude of the local heterodyne oscillations is L and that of the incoming signals is I, then the amplitude of the beats will vary from a maximum of $L + I$ to a minimum of the difference between L and I. When L is greater than I the average beat current, when rectified, will be proportional to

$$\frac{(L+I)-(L-I)}{2} = I,$$

that is, the signal strength will be proportional to the amplitude of the incoming signals. Hence a nearby station would drown a distant station. If the amplitude of the local oscillations is less than that of the incoming waves the average rectified beat current will be proportional to

$$\frac{(I+L)-(I-L)}{2} = L,$$

that is, the signal strength is proportional to the amplitude of the local current. Under these conditions a very high power station would not give any louder signals than a weak distant station. This effect has been found in practice to be very useful to prevent excessive interference.

The discussion was opened by Dr. J. ERSKINE-MURRAY who thought that the arrangement described might be very useful for ground stations but would probably be too complicated for aircraft work. He also expressed interest in the explanation given of the effect of the relative magnitude of the local and heterodyne oscillations.

Major N. HAMILTON, Mr. BASIL BINYON, Mr. PHILIP R. COURSEY, Mr. R. C. CLINKER, and Mr. BROADWOOD discussed the radiation from such circuits from various points of view. The question was also raised as to the relative magnification of a heterodyne note and a spark signal note by the note magnifier of the (C) circuit. In connection with the measurement of the frequency of continuous waves Mr. R. C. CLINKER described the double click method recently outlined by Dr. L. W. Austin. Mr. BROADWOOD suggested that it might be possible to use the receiving valve only as a detector and then to pass on the rectified energy from this valve to react with a separate circuit which may be made to oscillate at an acoustic frequency, and thus obtain a species of low-frequency heterodyne. Such an arrangement might avoid some of the difficulties of the heterodyne radiation.

Mr. SCOTT-TAGGART in reply pointed out that the circuit described was not intended to eliminate heterodyne radiation but merely to reduce it, and dealt with the relative merits of self-heterodyne and separate heterodyne arrangements.

He also outlined a slight modification of the circuits with a view to lessening the number of separate batteries required.

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Review of Radio Literature.

1. Abstracts of Articles.

88. THE CALCULATION OF ANTENNA CAPACITY. L. W. Austin. (*Journal, Washington Academy of Sciences*, 9, pp. 393—396, August, 1919.)

The predetermination of antenna capacity has until recently been a matter of great uncertainty. The author refers to the most important contributions to the subject, and then deals with the results of recent measurements on various forms of aerials. It was discovered empirically that the capacities of all antennas not too elongated in shape and having their wires not too widely spaced can be very approximately represented by the formula:

$$C = (4\sqrt{a} + 0{\cdot}88\,a/h) \times 10^{-5}, \text{ mfds.},$$

where a = area of aerial; and h = its mean height, both in metres. When the length l of the aerial is more than eight times its breadth b, an elongation factor must be introduced into the above formula:

$$C = (4\sqrt{a} + 0{\cdot}88\,a/h)\,(1 + 0{\cdot}015\,l/b) \times 10^{-5}, \text{ mfds.}$$

These equations are really the sum of the usual expressions for the capacity of a disc in space and that for a two-plate condenser, disregarding the edge effect. Results correct to 10 per cent. for the antenna top. Capacity of downleads etc. must be added. Formulæ assume that wires are sufficiently close to obtain nearly full capacity for the flat top of the aerial. Comparisons of calculated and observed capacities are given.

89. THE CALCULATION OF THE NATURAL WAVELENGTH OF AERIALS. A. Meissner. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 269—270, August, 1919.)

The author maintains that Howe's method is too complicated and lengthy for practice and does not give accurate results. He prefers the cruder method of multiplying the length measured along the wire from earth to extremity of aerial by a coefficient found by experiment for different types of aerials.

Examples:	Vertical wire	$4l$—$4{\cdot}1l$
	Horizontal wire, 1 metre above ground	$5l$
	Broader aerials	$5l$—$7l$
	Old Nauen **T** aerial . . .	$5{\cdot}5l$
	Small **T** (ships)	$4{\cdot}5$—$5{\cdot}0l$
	New Nauen **T** (broad) . . .	$5{\cdot}8l$
	T (breadth = l, height = $l/2$ to $l/3$)	$9l$—$10l$
	Umbrella	$6l$—$8l$
	Ditto, low, with many wires . .	$8l$—$10l$

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90. AIRPLANE ANTENNÆ CONSTANTS. J. M. Cork. (*Bureau of Standards, Scientific Paper*, No. 341, September, 1919. *Journal of the Franklin Institute*, 188, pp. 556—557, Abstract.)

The purpose of this experimental investigation was to devise a method for measuring the constants of various forms of aerials on aeroplanes. All the measurements were made under conditions of actual flight. The principle of the method involves the use of a continuous-wave valve oscillation generator for exciting the aerial directly and then substituting for the antenna a variable calibrated condenser and a variable calibrated non-inductive resistance. By this means the effective capacity and effective resistance are obtained. From these results the true capacity, inductance and natural wavelength are found graphically. Results were obtained for various forms of fixed wires and for one, two, and four trailing wires of various lengths. The results are summarised in a series of curves. An interesting result of these investigations is that under no circumstances was any rise in effective resistance of the aerial found with increasing wavelength, as compared with the results for aerials on the ground where the total resistance of the aerial first decreases rapidly and then rises again with increasing wavelength. This rise of resistance must therefore be due to the effect of imperfect dielectrics near the aerial such as the earth, etc., which are not present in the case of aeroplane aerials. The effect of covering the wings of the aeroplane with wire network with a view to improving the counter-capacity of the aeroplane was investigated, but the results were not so good as when the counterpoise connection was made to the ordinary metallic frame of the machine.

The method for finding the directional transmitting effect of various aerials is also described in the paper. In order to compare the amounts of energy received, a detector valve with a three-stage low-frequency amplifier was used. A transformer was placed in the plate circuit of the last valve, and its secondary connected to the heater coil of a thermo-couple joined to a D.C. microammeter. This receiving arrangement was found to be free from many of the uncertainties of ordinary audibility meters. A typical directional transmission curve for a trailing wire aerial is included in the paper.

91. RADIATION FROM COMPOUND ANTENNÆ. M. Abraham. (*Archives für Elektrotechnik*, 8, pp. 42—45, July, 1919. *Technical Review*, 5, p. 80, October, 1919, Abstract.)

Assuming that two antennæ radiating synchronously and having their capacity to earth mainly concentrated in the horizontal portions are erected in close proximity, each will induce currents in the other and the energy required to maintain them in oscillation is greater than the sum of the amounts required to maintain each of them individually in oscillation. There is an increased radiation from the antennæ resulting from the superposition of their fields. This increase vanishes when the oscillations of the antennæ are displaced in phase by a quarter of a period. A general expression is

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worked out for the sum of the radiations for any phase displacement between the oscillations of the component antennæ, both for the radiations along the earth's surface and also for the total radiation. The case is also considered of two antennæ one of which is excited by the transmitter while the other one is entirely separate but tuned to the same frequency. This shows that if the secondary antenna has a certain resistance and is at a given distance from the primary antenna a complete shadow is thrown by the auxiliary antenna, while radiation from the main antenna is increased in the opposite direction by a species of mirror action. Such a secondary antenna may also be used at a receiving station to screen the main aerial from undesired radiations. The conditions for such screening to be effective are worked out. Two secondary antennæ closely coupled together by their fields and situated at such a distance from a single primary antenna as not to react upon it appreciably, produce the same effect as a single secondary antenna of twice the radiation resistance.

92. RELIABLE METHOD FOR THE APPROXIMATE DETERMINATION OF THE TRUE ANTENNA CONSTANTS. A. Hund. (*Electrician*, 83, p. 470, October, 1919.)

The procedure described was based on the measurement of the wavelengths λ and λ' for the unloaded and coil loaded antenna. The inductance added at the base of the aerial must be sufficient to increase its wavelength to at least twice the fundamental value. The true or static antenna constants are calculated from the formulæ

$$L_A = \frac{3\pi^2\lambda^2}{12\lambda'^2 - \pi^2\lambda^2} L_0 \text{ henrys.} \quad C_A = \frac{10^{-10}}{144} \cdot \frac{\lambda^2}{L_A} \cdot \text{mfds.}$$

where λ is in metres and L_0 in henrys.

This formulæ applies more rigidly as the value of the loading inductance is increased. Many measurements show that this formulæ holds for almost all commercial antennæ to a very close approximation. A table of some typical results is given showing errors not greater than about 2 to 3 per cent. as compared with the theoretical calculated constants.

93. INDUCTANCE, CAPACITY AND RESISTANCE OF COILS AT RADIO FREQUENCY. L. E. Whittemore and J. Breit. (*Physical Review*, 14, pp. 170—172, August, 1919, Abstract of Paper read before the American Physical Society.)

Inductances used in radio circuits may usually be considered as pure inductances shunted by a capacity representing the distributed capacity of the coil. The pure inductances can most conveniently be determined from the values of the apparent inductance as obtained from the capacity which is required to give resonance at certain frequencies. The pure inductance and distributed capacity of the coil may be obtained from the data used for plotting the apparent inductances curve by the use of the following formulæ:

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$$C_0 = \frac{(\Sigma C_1)(\Sigma \lambda_1^4) - (\Sigma \lambda_1^2)(\Sigma C_1 \lambda_1^2)}{-N\Sigma \lambda_1^4 + (\Sigma \lambda_1^2)^2}$$

$$L_0 = \frac{0{\cdot}2814\,[N\Sigma \lambda_1^4 - (\Sigma \lambda_1^2)^2]}{-(\Sigma C_1)(\Sigma \lambda_1^2) + N\Sigma C_1 \lambda_1^2}$$

C_0 and C_1 being expressed in micromicrofarads, L_0 in microhenries, and λ in metres. N is the total number of observations from which C_0 and L_0 are calculated. C_1 and λ_1 are corresponding values of the capacity in series with the coil and the resonant wavelength. It is assumed for the derivation of these formulæ that the error in the capacity measurement is constant, and that the percentage of accuracy in the wavelength measurements is also constant. If the coil whose capacity is to be obtained is immersed in a liquid of dielectric constant K, the capacity of the coil C_0 is

$$C_0 = \frac{C_1 - C_2}{K - 1}$$

where C_1 and C_2 are the capacities required to tune the coil to resonance with a certain frequency before and after the coil is immersed in the liquid. The capacity of a coil to earth is important in many cases. If two condensers C_1 and C_2 are joined in series with a coil and the point of connection between the condensers is earthed then for a symmetrical coil its capacity to earth is given by the expression :

$$C_g = 4\left[\frac{C_1C_2}{C_1 + C_2}\ (\text{max.}) - \frac{C_1C_2}{C_1 + C_2}\ (\text{min.})\right]$$

The maximum is obtained when $C_1 = C_2$. The minimum value of $C_1C_2/(C_1 + C_2)$ is obtained when either C_1 or C_2 is short-circuited. The following empirical expression was found to represent the curve connecting the high frequency resistance of the coil and the wavelength

$$R = A + \frac{B}{(\lambda^2/\lambda_0^2) - 1}$$

Where R is the resistance at wavelength λ, and where A, B, and λ_0 are constants of the coil.

94. STUDY OF ELECTROSTATICALLY COUPLED CIRCUITS. W. O. Lytle. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 427—444, August, 1919.)

This paper deals with the mathematical theory of electrostatically coupled circuits as worked out by L. E. Whittemore of the Physics Department of the University of Kansas. The solution of the problem is worked out by treating the circuits in the same manner as is done with ordinary alternating current problems using the vectorial notation. Two conditions of the circuit are dealt with (1) when they are tuned together after coupling and (2) when they are tuned before coupling together. In the former case it is shown that as the coupling is increased one of the resultant wavelengths approaches infinity and the other approaches zero but in the case when the

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circuits are tuned together before coupling one wavelength always remains constant while the second approaches infinity with a steadily reducing energy. This latter case is considered as an ideal condition since it enables a large proportion of the primary energy of a coupled transmitter to be transferred to the secondary and yet to retain in effect a radiation of a single wavelength only. The results of the mathematical investigation were confirmed by means of oscillograms taken with a Braun tube oscillograph using an oscillating arc as generator. The type of coupling employed is

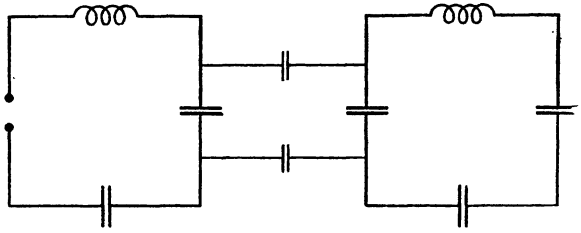

FIG. 1.

indicated in Fig. 1 and couplings up to 92 per cent. were obtainable. The curve of the current in the secondary circuit plotted against percentage coupling as obtained in one of these tests is given in Fig. 2 from which

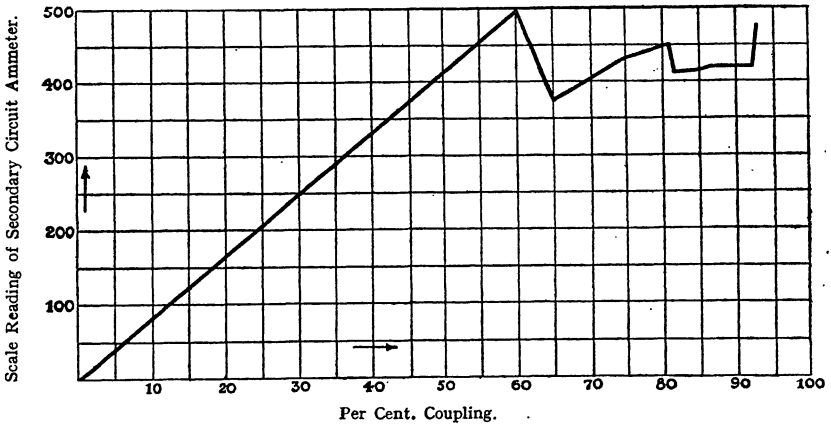

FIG. 2.

it will be seen that three current maxima were found. The first at 60 per cent. coupling was found to correspond with the case when the ratio of the second "coupling wavelengths" was 2 to 1; the second at 80 per cent. coupling corresponds to a wavelength ratio of 3 to 1 and the third at 92 per cent. with a ratio of 5 to 1. That is to say when the ratio of the two resultant frequencies is an integer the secondary current reaches a maximum value.

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It is concluded from the experiments that electrostatic coupling should be given a place in practical radio work, firstly because a high percentage coupling can be easily obtained and secondly because when such close coupling is used there is practically only one wavelength in the circuit. A useful application of electrostatic coupling that is mentioned in the paper is that of transmitting on a short wave harmonic on a large aerial without unduly reducing the radiated energy.

95. IMPROVEMENTS IN PRECISION MEASUREMENTS AT RADIO FREQUENCIES. J. H. Dellinger. (*Physical Review*, 14, pp. 181—183, August, 1919, Abstract of Paper read before the American Physical Society.)

This paper briefly reviews, without great detail, the wartime work of the Bureau of Standards on various methods of high frequency measurements.

96. HIGH FREQUENCY MAGNETISATION—THE OLD AND THE NEW POINT OF VIEW. H. Fassbender. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 222—243, August, 1919.)

After reviewing earlier work dealing with the well-known fact that at high frequencies iron appears to have a very low permeability, the author states that the mistaken idea that this is due to molecular inertia or viscosity is not altogether extinct, although magnetic skin effect was investigated by Heaviside in 1892, and by J. J. Thomson in 1893. Fassbender and Hupka have made a number of tests of sheet-iron rings magnetised with high frequency current, and magnetisation curves obtained with a cathode ray oscillograph are reproduced. Owing to eddy currents in the iron neither **H** nor **B** are uniform throughout the iron and the **B**—**H** curves obtained are meaningless. The author calculates the effective values of **H** and **B** throughout the iron in several cases and finds agreement with experimental results. Some of Alexanderson's results at $f = 200{,}000 \sim$ are reproduced and reference is made to recent work by Kühn, Osnos, McLachlan and Arkadieff. At radio frequencies there is no appreciable decrease in the actual permeability of iron, any apparent decrease being due to the demagnetising effect of eddy currents. At considerably higher frequencies, however, the author believes that there is evidence of a considerable decrease.

97. ACTIVITIES OF THE REICHSANSTALT DURING 1918. (*Elektrotechnische Zeitschrift*, 40, p. 498, October, 1919.)

The only reference to radiotelegraphy is in connection with the introduction of new standards of wavelength due to the greater accuracy demanded since the introduction of thermionic generators. The basis consists of a number of oscillating circuits with fixed inductance and capacity; from the measured inductance and capacity the wavelength is calculated. These together with the harmonics give fixed points on other wave meters with variable condensers.

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98. MEANS FOR DETECTING SMALL ELECTRIC CURRENTS. J. S. E. Townsend. (*British Patent* 130429, February, 1918. Patent accepted, August 7th, 1919.)

An incandescent lamp used as a current indicator for a wave meter is rendered more sensitive to small currents by priming with a small direct current, so as to bring the lamp nearly to the point where incandescence commences.

99. AN ARRANGEMENT FOR SETTING UP OSCILLATIONS OF SINGLE FREQUENCY ONLY. E. Bellini. (*French Patent* 493249, January, 1916. Published August 2nd, 1919.)

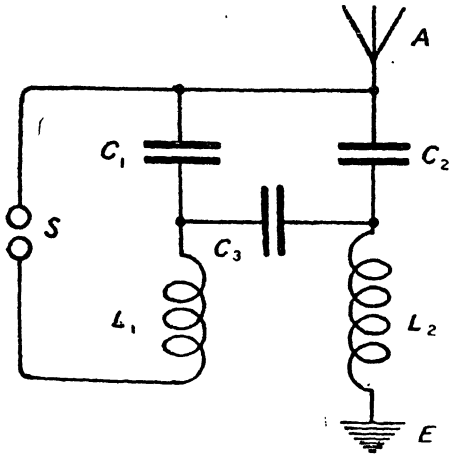

FIG. 3.

A number of arrangements are described for the use of a combined electric and magnetic coupling between two circuits. One of these circuits may be the transmitting or receiving aerial circuit. It is claimed that oscillations of a single frequency only may be set up by this means. One arrangement for transmitting is indicated in Fig. 3. An analogous arrangement may be used for receiving. See also RADIO REVIEW, Abstract No. 22.*

100. ELECTRODYNAMIC AMMETER FOR ALL FREQUENCIES. Compagnie Générale de Radiotélégraphie. (*French Patent* 493297, March, 1916. Published August 5th, 1919.)

101. THERMAL ARRANGEMENT FOR THE ACCURATE MEASUREMENT OF CURRENTS OF HIGH OR LOW FREQUENCY. D. du Rousset. (*French Patent* 493456, July, 1916. Published August 9th, 1919.)

A special construction of thermal ammeter.

102. THE INDUCTANCE OF SINGLE LAYER RECTANGULAR COILS. G. W. O. Howe. (*Radio Review*, 1, pp. 124—126, December, 1919.)

* Some experimental investigations of these circuits are described in RADIO REVIEW Abstract No. 94.

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103. SIMPLIFIED INDUCTANCE CALCULATIONS WITH SPECIAL REFERENCE TO THICK COILS. P. R. Coursey. (*Wireless World*, 7, pp. 380—385, October, 1919.)

Abstract of paper read before the Physical Society of London, giving an extension of Nagaoka's formula for single layer solenoids in the form of a set of curves applicable to thick and multilayer coils.

104. A NOTE ON THE COMPARISON OF INDUCTANCE, OR OF AN INDUCTANCE AND A CAPACITY, BY AN ELECTROMETER METHOD. A. W. Smith. (*Physical Review*, 14, pp. 356—360, October, 1919.)

This method makes use of an electrometer whose quadrants are connected across a condenser in series with the inductance to be measured and whose needle is joined to the centre point of a high non-inductive resistance shunting the condenser and inductance. It is shown that the deflection of the electrometer is proportional to the inductance, to the square of the current and inversely proportional to the capacity. Experimental verification of these relations is given. The method is most sensitive when working near the resonant frequency of the capacity-inductance circuit, but the results are independent of the frequency and wave form of the A.C. supply. The results were found to be in agreement with measurements on an A.C. bridge.

105. A HIGH EFFICIENCY 1 KW. TRANSMITTER. (*Everyday Engineering Magazine*, 7, pp. 360—362, September, 1919.)

This paper describes a new quenched gap set constructed by the International Radio Telegraph Company. Views of the instruments are given. The efficiency measured on an 8-ohm aerial is 51·2 per cent.

106. RADIOTELEGRAPHIC AND TELEPHONIC STATIONS. T. G. Simpson. (*French Patent* 492850, December, 1916. Published July 19th, 1919.)

The claims cover a transmitting apparatus for radio communication comprising an oscillating circuit, an aerial and earth connection, and a charging circuit for the spark gap, the connections of which are made at nodal points in the oscillating circuits. Alternatively the connections may be made near the nodal points so that the oscillating currents have a small tendency to traverse the spark gap.

107. IMPROVEMENTS IN HIGH-FREQUENCY OSCILLATION GENERATORS. V. Bouchardon. (*French Patent* 493222, November, 1918. Published August 2nd, 1919.)

The object of the invention is to combine the advantages of C.W. transmission with those of spark systems. It consists in the use of the same generating apparatus for feeding the two transmitting arrangements using sparks or three-electrode valves. A polyphase supply may be employed

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with the same number of valves as phases. The change from damped to C.W. transmission can be effected rapidly by suitable switches.

108. PRODUCING ELECTRIC OSCILLATIONS. J. Bethenod. (*British Patent* 126019, November, 1915.)

Electric oscillations are produced by means of a vacuum tube having a cathode, two anodes, and two auxiliary plate electrodes for oscillating the cathode-ray beam from one anode to the other by means of an alternating electrostatic field. The alternating electric field is produced by the action of the tube itself, and is derived from a secondary circuit coupled with the discharge circuits through the two anodes. The frequency of the oscillations is determined by the natural oscillation frequency of this secondary circuit.

109. SPARK GAP FOR HIGH FREQUENCY. Compagnie Générale de Radiotélégraphie. (*French Patent* 493336, March, 1916. Published August 6th, 1919.)

A rotary spark gap arrangement.

110. LOWENSTEIN'S QUENCHED GAP. (*Wireless Age*, 6, p. 19, September, 1919.)

An illustrated description of a quenched gap due to F. Lowenstein, of which each unit takes the form of two concentric metallic cylinders. The spark gap is between the inner and outer cylindrical surfaces.

111. IMPROVEMENTS IN RADIOTELEGRAPHIC APPARATUS. L. M. Cockaday. (*French Patent* 493433, November, 1918. Published August 8th, 1919. *Wireless Age*, 7, p. 31, October, 1919.)

The arrangement consists of a transformer with its primary connected to a supply circuit (preferably D.C.) through a make-and-break contact. The spark gap fed from the secondary of this transformer is preferably mechanically coupled to the make-and-break.

112. LOW POTENTIAL RADIO FREQUENCY ARC. C. W. Noller. (*Radio Amateur News*, 1, pp. 70—71, August, 1919.)

A special arc apparatus for low power short wave work and suitable for use on a 110-volt supply circuit. The arc consists of two tungsten electrodes operating in a liquid consisting of alcohol or petrol, mixed with a 10 per cent. solution (by volume) of ammonia. Two or more shunt oscillation circuits are connected across the arc tuned to lower frequency harmonics of the required oscillation frequency. Wavelengths down to 100 metres with a power of 80 watts upwards are possible. Great steadiness is claimed. The complete arc is mounted in a metal container with cooling flanges, and the normal p.d. between the electrodes is 55 volts when operating in a 110-volt circuit. Overall efficiency to aerial circuit = 24 per cent.

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113. A NEW STRIKING ARRANGEMENT FOR ARC OSCILLATION GENERATORS. D. du Rousset. (*French Patent* 493366, March, 1916. Published August 7th, 1919.)

114. THE DEVELOPMENT OF ARC RADIO TRANSMITTERS. A. L. Anderson and H. F. Elliott. (*Electrical World*, 74, pp. 452—456, August, 1919.)

A general description is given of the types of arc apparatus manufactured by the Federal Telegraph Co., with illustrations of a 5-kw. and a 200-kw. arc. The usual sizes that are manufactured are 5, 20, 30, 60, 100, 200, 350, 500, and 1,000 kw., the rating being reckoned on the D.C. input. The efficiencies of these sets range between 33 per cent. and 50 per cent. For ship work sizes up to 30 kw. are customarily used with wavelengths between 1,000 and 5,000 metres; while the larger sizes are reserved for large land stations, working on wavelengths of 2,000 to 15,000 metres. The arcs are joined directly in the aerial circuit, and are usually fed with direct current at 500 to 600 volts. The requisite strength of the magnetic field is a function of the power, frequency and nature of gaseous atmosphere surrounding the arc, and it is stated that definite mathematical " design " relations exist between these factors although they are not given in the article. With the smaller arcs ($<$100 kw.) open magnetic circuits are used, but for the largest sizes closed cores are employed to obtain the necessary magnetic field strength. For the smaller arcs alcohol is usually employed to provide the hydrocarbon atmosphere; but in the larger sizes and to obtain considerable power on short wavelengths kerosene is used. This material increases the aerial current when the magnetic field is weak, but is apt to give a deposit of soot in the arc chamber. Coal gas is preferable.

Three types of signalling arrangements are described. (1) the compensation method, in which the signalling key short-circuits a few turns of the aerial inductance; (2) the coupled compensation method, in which the key short-circuits a small loop coupled to the aerial inductance; and (3) the ignition key signalling system, in which the arc is mechanically short-circuited through a resistance between the signalling periods. The second method is the most preferable; with small powers (5 kw.) one loop and short circuiting key is used, for larger sizes several loops are employed, each fitted with an electro-magnetically operated short circuiting key. For a 100-kw. arc twelve such loops and keys are required. The third method is only suitable for very small power units.

115. ARC LAMP FOR THE PRODUCTION OF ELECTRICAL OSCILLATIONS. L. Mauclaire, A. Garbarini, G. Gautier. (*French Patent* 493769, December, 1916. Published August 21st, 1919.)

In the arrangement of arc described a central electrode of carbon or other good conducting material is surrounded by a hollow metallic ring forming the second electrode through which a cooling liquid is circulated.

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116. RECTIFYING HIGH-TENSION ALTERNATING CURRENTS. S. Cohen. (*Electrical World*, 74, pp. 573—575, September, 1919.)

A practical application of the rectifying properties of a point-plate spark gap for obtaining high-tension direct current. Best results with Copper-Aluminium or Iron-Aluminium electrodes, with a jet of gas through the centre of the copper or iron electrode. The effect of various gases on efficiency is

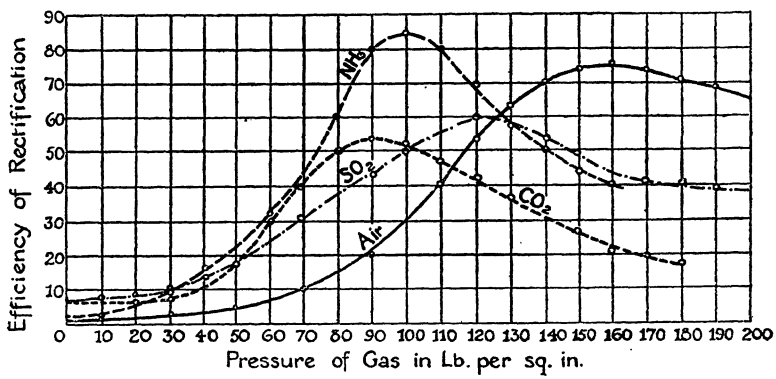

FIG. 4.

shown in Fig. 4. The use of a rotating disc for the aluminium-electrode increases the stability.

117. THE GENERATION OF HIGH-TENSION DIRECT CURRENT. M. Schenkel. (*Elektrotechnische Zeitschrift*, 40, pp. 333—334, July, 1919; also *German Patent* 310356.)

A special arrangement of cascaded valve rectifiers is described for obtaining H.T. direct current from an A.C. supply. The arrangement is sketched in Fig. 5. The first valve V_1 rectifies the A.C. supply and charges up the

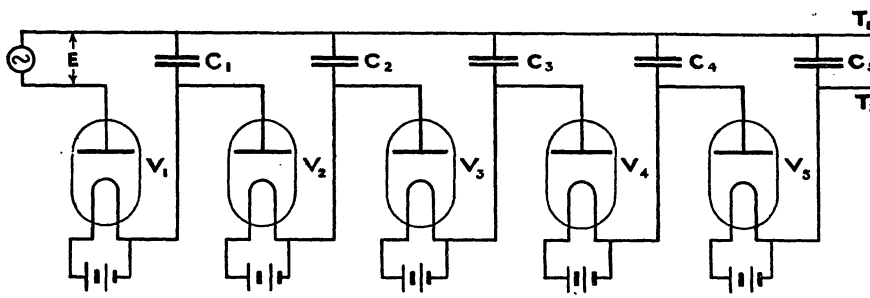

FIG. 5.

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condenser C_1 to approximately 1·4 E volts D.C. In the reverse half-cycle when no current passes through the valve, the supply voltage E is added to the voltage of condenser C_1 across the valve terminals. This voltage is applied to valve V_2 and condenser C_2 so that the latter is charged to a voltage of 2·8 E, and so on for the other valves. With five valves as shown the D.C. voltage between T_1T_2 becomes 7·0 E. The maximum voltage obtainable in this manner is limited solely by the insulation of the system. The capacity of the condensers must be proportioned to the working voltage of each and to the output current to be obtained from the system.

118. ARRANGEMENTS FOR RECTIFYING ALTERNATING CURRENTS BY MEANS OF VALVES. M. Latour. (*French Patent* 493662, August, 1917. Published August 19th, 1919.)

This refers to the use of A.C. for heating the filaments of rectifying valves. (See also Abstract No. 119.)

119. RECTIFYING ALTERNATING CURRENTS. M. Latour. (*British Patent* 131697, August, 1917. Patent accepted, September 4th, 1919.)

For rectifying an A.C. supply the secondary winding L_1 of transformer T is connected to two valves V_1 V_2 in opposite directions, condensers C_1 C_2

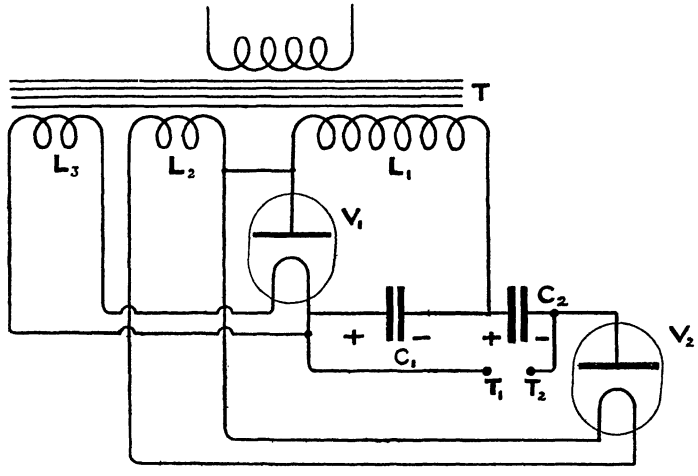

FIG. 6.

being included in the circuits as shown. The valve filaments are heated by auxiliary winding L_2 L_3 on the same transformer. The D.C. circuit is joined to T_1 T_2 so that the D.C. supply is drawn from the two condensers C_1 C_2 in series.

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120. PRODUCING ELECTRIC OSCILLATIONS. G. Bethenod. (*British Patent* 130614. July, 1918.)

An addition to British Patent 128575 (RADIO REVIEW Abstract No. 23) providing for: the connection of the secondaries of the separate coupling transformers in parallel or in series-parallel instead of in series, the connection of all the alternator windings and transformer primaries in a simple series circuit, and the earthing of the mid-points of the alternator windings and transformer primaries.

121. IMPROVEMENTS IN RADIO SIGNALLING SYSTEMS. L. de Forest. (*British Patent* 131361, June, 1917. Patent accepted, August 28th, 1919.)

An arrangement of 3-electrode valve for transmission, as indicated in

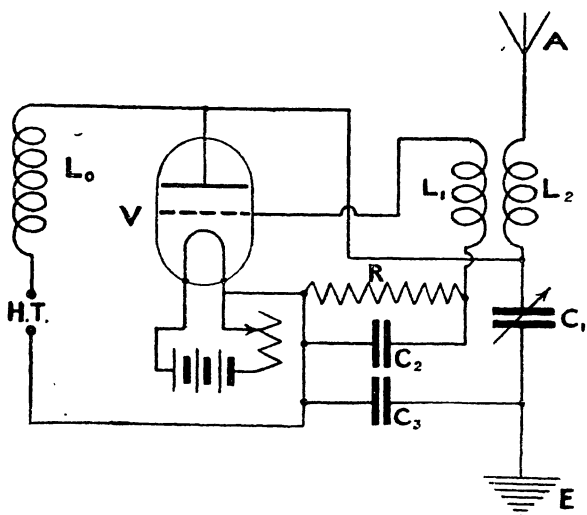

FIG. 7.

Fig. 7. The signalling arrangement is joined in series with the grid-circuit resistance R.

122. ARRANGEMENTS FOR RADIOTELEGRAPHIC AND RADIOTELEPHONIC TRANSMITTERS USING HIGH-FREQUENCY AMPLIFIERS. Société Française Radioélectrique. (*French Patent* 493821, August, 1916. Published August 22nd, 1919.)

An arrangement of transmitter in which the oscillations are generated either in one or in a group of three-electrode valves and subsequently amplified by additional valve amplifiers before connection to the transmitting aerial. Transformers or other couplings may be used between the valves. Provision

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is made for the use of the same set of valves for either transmission or reception purposes by means of a suitable switch for effecting the necessary changes of connection.

123. A RELAY ARRANGEMENT FOR INDICATING THE FAILURE OF VACUUM TUBE FILAMENTS. M. Latour. (*French Patent* 493204, October, 1917. Published July 29th, 1919.)

A differential relay is used of which one winding is connected in series with the valve filament and the other with a shunt circuit connected across the supply battery.

124. AN ARRANGEMENT FOR THE USE OF TWO OR MORE OSCILLATION GENERATORS FOR UNDAMPED WAVES. D. du Rousset. (*French Patent* 493458, July, 1916. Published August 9th, 1919.)

125. THE PLIOTRON OSCILLATOR. W. C. White. (*Electrical Experimenter*, 7, p. 232, July, 1919.)

Describes two uses of the pliotron oscillator. (1) For the production of relatively large current, and (2) the production of relatively large voltage, the energy involved in each case being of the order of 150 watts or less.

126. "HELLO, EUROPE!"—VIA RADIO. C. M. Ripley. (*Electrical Experimenter*, 7, p. 210, July, 1919.)

A detailed description of the New Brunswick, N.J., wireless station.

127. IMPROVEMENTS RELATING TO ELECTRON DISCHARGE DEVICES. The General Electric Co., U.S.A. (*British Patent* 130400, February, 1918. Patent accepted, August 7th, 1919.)

In a high-vacuum tube acting as a "negative resistance," the stream of electrons is subjected to a magnetic field, so as to vary the number impinging on the third electrode. The magnetic field is provided by a coil surrounding the tube and coaxial with the filament. Varying currents passed through this coil are amplified by the device. The tube may serve as a radiotelephone transmitter, by employing its "negative resistance" to set up oscillations in the usual manner, and modulating these by speech currents passed through the outer coil.

128. IMPROVEMENTS RELATING TO WIRELESS SIGNALLING SYSTEMS. The General Electric Co., U.S.A. (*British Patent* 130369, February, 1918. Patent accepted, August 7th, 1919.)

A wireless transmitting apparatus employing modulated continuous waves has the aerial tuned to a frequency equal to the sum or difference of the wave frequency and the modulating or amplitude pulsation frequency, and the circuit of the source of oscillations tuned to the frequency of the source. When several modulating frequencies are employed (see RADIO REVIEW Abstract No. 30) the aerial is tuned to the wave frequency plus the highest

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modulating frequency. For speech currents the aerial is tuned to the wave frequency plus the mean speech frequency (800 to 1,000~).

129. IMPROVEMENTS RELATING TO HIGH-FREQUENCY ELECTRIC INSTALLATIONS. G. A. Beauvais. (*British Patent* 131018, March, 1918. Patent accepted, August 21st, 1919.)

In a system for producing electric oscillations using a three-electrode valve, a resistance shunted by a condenser is placed in the grid circuit of the valve, and the potential at the terminals of the resistance is varied by the action of a microphone or by an independent oscillating circuit. The modulations produced by the microphone may be first amplified by an additional valve before they are applied to control the p.d. on the grid circuit resistance of the oscillating valve. One arrangement is shown in Fig. 8. V is the oscillation valve and R the resistance in its grid circuit. K represents the amplifier between the microphone M and the resistance R. C_2 C_3 are blocking condensers. In alternative arrangements the resistance R is replaced by the "internal-resistance" of a second valve, V_1, Fig. 9, upon the grid of which the microphone modulations are impressed. This second valve (V_1) is shunted by the condenser C_1, just as the resistance R (Fig. 8) is similarly shunted. Additional intermediate valve amplifiers may also be used. For telegraphic purposes this second "control" valve may be arranged to generate oscillations of musical frequency.

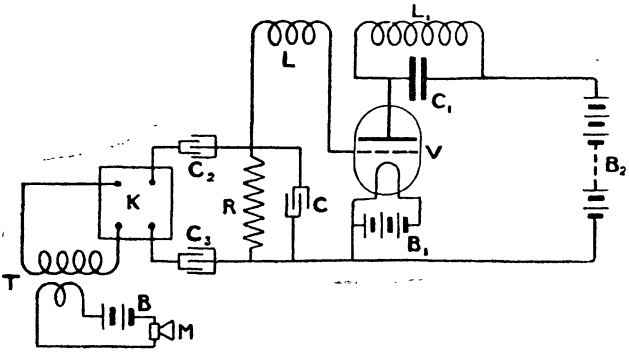

FIG. 8.

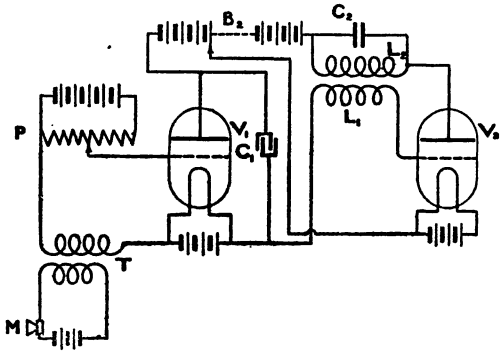

FIG. 9.

130. CONTINUOUS CURRENT MACHINES SPECIALLY APPLICABLE TO WIRELESS TELEPHONY. J. Bethenod. (*French Patent* 493492, August, 1916. Published August 9th, 1919.)

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131. A NEW MODULATION ARRANGEMENT FOR WIRELESS TELEPHONY. D. du Rousset. (*French Patent* 493457, July, 1916. Published August 9th, 1919.)

For the modulation of the transmitting antenna current a number of separate microphones are employed each connected to a small loop coupled to the aerial circuit. The microphones are all arranged to be influenced by a common mouthpiece.

132. IMPROVEMENTS RELATING TO RADIOTELEPHONE TRANSMISSION SYSTEMS. General Electric Company (U.S.A.). (*British Patent* 131553, March, 1919. Patent accepted, August 28th, 1919.)

A radiotelephone transmitter is described for which the oscillatory energy is generated in a single valve V_1, Fig. 10, and thence passes through three

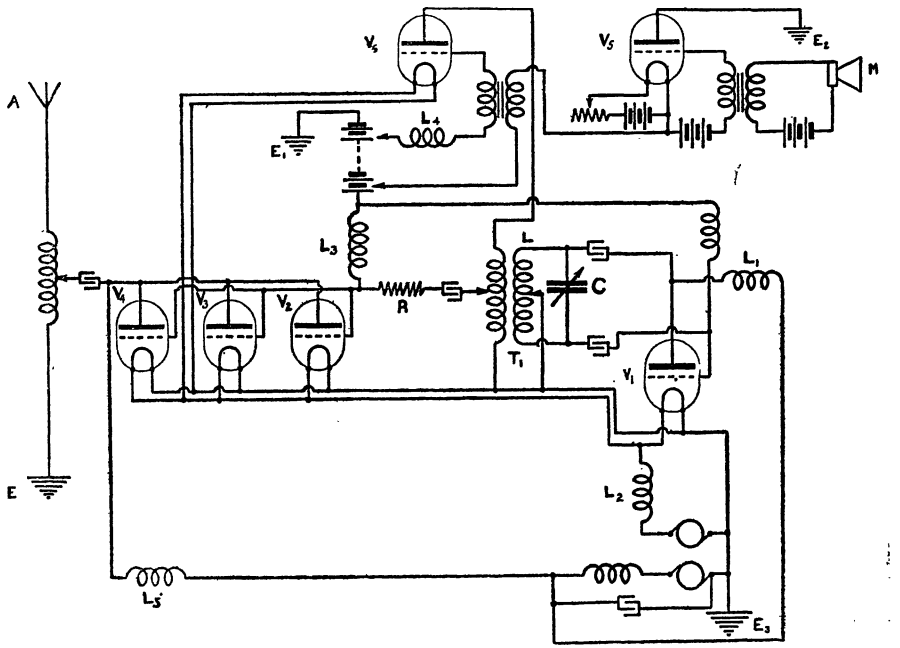

FIG. 10.

amplifying valves in parallel V_2 V_3 V_4 before coupling to the aerial. Modulations from the microphone M are amplified by the valve V_5 and impressed upon the grid circuit of the modulating valve V_6. The plate circuit of this valve is connected to the secondary of the transformer serving also to couple the oscillation valve with the main amplifiers. Circuit L C is tuned to the oscillation frequency of V_1. The resistance R between the secondary of T_1 and the amplifying valves V_2 V_3 V_4 serves to prevent these amplifiers

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setting up sustained oscillations. The choke coils L_1 L_2 L_3 L_4 L_5 are to prevent the passage of high-frequency currents into the low-frequency circuits. They are adjusted so that their natural frequencies are as nearly as possible the same as the high-frequency oscillations, so that they offer increased impedence to the passage of the currents of this frequency.

133. DEVELOPMENTS IN WIRELESS TELEPHONY. F. B. Jewett. (*Radio Amateur News*, 1, p. 71, August, 1919.)
A general article summarising recent progress.

134. RECENT PROGRESS IN RADIOTELEPHONY. C. Schmitt. (*L'Électricien*, 49, pp. 187—188, October, 1918.)
A short article reviewing the various types of transmitters available for radiotelephony, including the various arrangements of spark gaps suitable for very high frequencies.

135. TRANSATLANTIC WIRELESS TELEPHONY. J. A. Fleming. (*Electrician*, 83, p. 463, October, 1919, Abstract. *Wireless World*, 7, pp. 499—501.)
Report of a lecture describing recent achievements.

136. A REVIEW OF RADIOTELEPHONY. (*Electrical Experimenter*, 7, p. 326, August, 1919.)
A very brief historical account of radiotelephonic development. Diagrams are given of a U.S. battleship set and a U.S. signal corps set.

137. IMPROVEMENTS RELATING TO AUDION AMPLIFYING APPARATUS. M. Latour. (*British Patent* 131362, October, 1917. Patent accepted, August 28th, 1919.)
In a cascade amplifier using three-electrode valves—particularly for radiotelephone transmission purposes, for amplifying the speech currents—each successive stage either has larger valves or has a greater number of valves in parallel. Higher anode voltages may also be used on successive stages. It is recommended that the microphone should be connected in one arm of a balanced bridge, across one diagonal of which the H.F. source is joined, while across the other diagonal a transformer is connected for coupling to the input grid circuit of the above cascade amplifier.

138. WIRELESS TELEPHONY OVER 140 KILOMETRES. (*Elektrotechnische Zeitschrift*, 40, p. 512, October, 1919.)
The Telefunken Company report that telephonic communication was maintained between a station in Nuremberg and an airship up to a distance of 140 km.

139. THE AUTO RADIOPHONE. A. H. Grebe. (*Radio Amateur News*, 1, pp. 58—59, August, 1919.)
Radiotelephone apparatus used on a motor car, which carries its own aerial structure enabling the set to be used while in motion.

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140. IMPROVEMENTS RELATING TO ELECTROMAGNETIC WAVE SIGNALLING SYSTEMS. N. Lea. (*British Patent* 130520, November, 1918. Patent accepted, August 7th, 1919.)

The proposed arrangement for a wireless telephone transmitter is indicated in Fig. 11. The potential on the grid leak R of the oscillating valve V_1 is used to determine the mean grid potential of the control valve V_2. Transformer T is used to apply the modulating potential to the grid circuit of V_2 from a transmitting microphone or other control circuit.

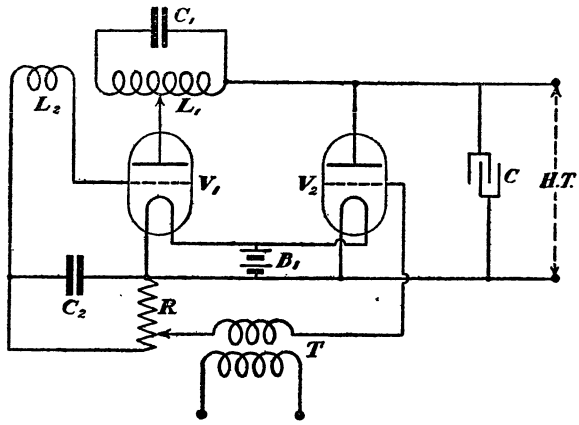

FIG. 11.

141. COPPER CONDUCTORS FOR LAMPS AND OTHER VACUUM TUBES. Société Nihon Denki Kogyo Kabushiki Kaischa. (*French Patent* 492967, November, 1918. Published July, 1919.)

A thin tube of copper is sealed through the glass for connection purposes.

142. THE DESIGN, PUMPING AND TESTING OF AUDION TUBES. C. Murray. (*Electrical Experimenter*, 7, p. 235, July, 1919.)

143. IMPROVEMENTS IN THE CONSTRUCTION OF VACUUM TUBES. Société Française Radioélectrique. (*French Patent* 493258, February, 1916. Published August 5th, 1919.)

The invention consists in placing the tube during exhaustion in a high-frequency alternating magnetic field so that the lines of magnetic force are as nearly as possible perpendicular to the surface of the electrodes. In this manner the electrodes behave as short-circuited secondaries to the coil producing the magnetic field, so that they are rapidly heated by the currents induced in them.

144. THEORY AND PRACTICAL ATTAINMENTS IN THE DESIGN AND USE OF RADIO DIRECTION-FINDING APPARATUS USING CLOSED COIL ANTENNÆ. A. S. Blatterman. (*Journal of the Franklin Institute*, 188, pp. 289—36·, September, 1919.)

A very comprehensive paper of seventy-three pages, recording a large amount of experimental work and discussion of results. The points investigated are :—

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(1) Best size of loop and number of turns for given wavelength.
(2) Effect of spacing the turns.
(3) Effect of size and kind of wire.
(4) Effect of insulation.
(5) Best size of tuning condenser.
(6) Effect of walls of building.
(7) Effect of dead turns on coil.

The voltage across the tuning condenser, *i.e.*, the voltage acting on the detector, is inversely proportional to the effective resistance of the coil, other things being equal; therefore this resistance was determined in all cases by exciting the loop circuit which included a thermo-galvanometer from an undamped tuned circuit and inserting known resistances. From the effective resistance R the "reception factor" $NAL/\lambda^2 R$ was calculated; N = turns, A = area, L = inductance, λ = wavelength. Both R and the reception factor are plotted against the wavelength for a great number of coils from 3 feet 6 inches up to 15 feet square, from 5 to 80 turns, and from $\frac{1}{4}$ inch up to $1\frac{1}{8}$ inch spacing. There is a value of λ for which the reception factor is a maximum; for shorter wavelengths R increases so rapidly that $\lambda^2 R$ increases. Curves and tables are given from which one can decide upon the best design for any given wavelength.

The second part of the paper is devoted to the directional characteristics of the loops. The deviation of the polar curve from the simple double circle is due to:—

(1) the displacement current effect,
(2) the antenna effect, and
(3) the shape effect.

(1) Owing to displacement currents from turn to turn there is a P.D. across the tuning condenser when the plane of the coil is normal to the signalling direction. The polar curve therefore has no zero value but merely two minimum points.

(2) The whole coil acts like an antenna, and, owing to one side having a lower capacity to earth than the other, *viâ* the filament battery and the operator's body, a P.D. is produced across the tuning condenser. Since this effect is unaffected by rotating the coil, it makes the two loops unsymmetrical and enables the operator to decide not only the line but the point of the compass from which the signal is coming.

(3) The so-called shape effect is merely the effect of the shape of the coil on the antenna effect.

For accurate work these various effects should be kept as small as possible. Pancake type coils have never such a sharp minimum as coils of the solenoid type. The results were checked by a number of experiments in the field. Beneficial results were obtained by arranging wires above the coil and using them as an earthed electrostatic shield. This improved the sharpness and symmetry without noticeably diminishing the strength of the signals. This is unnecessary if the loop and apparatus are raised 15 or 20 feet above the ground. The grounded shield reduced certain kinds of atmospherics.

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In conclusion it is mentioned that in their seven-bulb amplifiers the U.S. Signal Corps use iron-core intervalve transformers even in the radio frequency stages, the iron is stated to be 0·0015 inch thick.

145. IMPROVEMENTS IN RECEIVING ARRANGEMENTS FOR WIRELESS DIRECTION FINDING. Société Française Radioélectrique. (*French Patent* 493453, July, 1916. Published August 9th, 1919.)

Improvements in receiving arrangements for wireless direction finding comprise the use of a rectangular aerial with perpendicular diagonals which can be turned around a vertical diagonal. The turns of wire in this loop aerial are arranged parallel to one another and at least 2 cm. apart. It is recommended that all the apparatus as well as the operator should be very carefully insulated from one another and from the ground and that their relative positions should remain unchanged during a measurement.

146. IMPROVEMENTS IN REFLECTORS IN WIRELESS TELEGRAPHY AND TELEPHONY. C. S. Franklin and Marconi's Wireless Telegraph Company. (*British Patent* 128665, August, 1917. Patent accepted July 3rd, 1919.)

Electromagnetic waves are transmitted in, or received from, a desired direction, by parabolic reflectors comprising two or more sets of rods, strips, or wires arranged on the parabolic surface around the aerial as focus, each rod being tuned to the aerial. The focal distance is preferably one-quarter of the wavelength. The length of each rod is preferably about a half wavelength, but may be greater or less if a condenser or inductance is inserted. For short waves, no earth connections are necessary; but for long waves the aerial and lower rods of the reflector are preferably earthed.

147. DIRECTION FINDING BY WIRELESS TELEGRAPHY. H. R. Sankey. (*Electrical Review*, 85, pp. 509—512, 539—540, October, 1919. *Engineer*, 128, pp. 388—391.)

An abstract of a lecture delivered at the Shipping and Engineering Exhibition, Olympia, dealing in a general manner with D.F. apparatus, with illustrations of recent Marconi-Bellini-Tosi apparatus. A map of D.F. stations open for public service in the British Isles is given.

148. APPARATUS FOR THE CONCENTRATION OF ELECTRIC WAVES IN A SINGLE DIRECTION OR UPON A FIXED POINT. L. Rota and E. Binetti. (*British Patent* 131392, June, 1918. Patent accepted, August 28th, 1919.)

An addition to British patent 128624,* describing certain constructional details relative to the inner and outer cylinders referred to in that specification.

* RADIO REVIEW Abstract No. 42.

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149. SHORT WAVE RECEPTION AND TRANSMISSION ON GROUND WIRES (SUBTERRANEAN AND SUBMARINE). A. H. Taylor. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 337—362, August, 1919.)

This paper gives an historical review of the work of the U.S. Navy Research Department on the possibility of effective long distance reception with underground aerials. The most important property of these aerials demonstrated in the course of these experiments is the much greater ratio of signal strength to X-strength than is obtained with ordinary elevated aerials. These aerial systems were found to be markedly directional towards waves travelling in line with the length of the wires. The best length of wire was found to be independent of the direction from which signals impinged on the receiving station, and independent of the nature of the surrounding soil providing that it is reasonably damp. The best length also depends inversely upon the capacity per unit length of the wire used. Wire lengths from 100 to 2,000 feet were experimented with. The importance of very good insulation of the wires is particularly emphasised as tending to eliminate atmospheric interference. To such an extent is this the case that with very good insulation it has been found quite practicable to receive through strong local thunder storms. Reception is found to be enormously superior when the wires are buried in fresh water or wet soil than when suspended above the ground. Reception on these buried wires was found to follow the same law of diurnal and seasonal variation as is found on ordinary aerials. Signal strength fell off very rapidly after immersion of the wires in salt water, but in fresh water on long wavelengths no measurable decrease in signal strength was found down to a depth of 60 feet. Earthing of the wires at the outer ends reduced the signal strength by approximately 50 per cent. Continuous wave transmission from these aerials over a range of thirty-six miles was found possible using only 0·8 of an ampere in the buried aerial.

150. IMPROVEMENTS IN WIRELESS SIGNALLING SYSTEMS. J. H. Rogers, H. H. Lyon, F. S. Hill. (*French Patent* 493539 and 493540, November, 1917. Published August 12th, 1919.)

This relates to low horizontal " earth " antennæ placed either close to or just below the surface of the earth or water.

151. SOME MODERN VACUUM TUBE CIRCUITS AND THEIR OPERATION. J. Scott-Taggart. (*Wireless Age*, 7, pp. 25—27, October, 1919.)

The circuits described are :—

(1) A " standby " and " tuned " continuous wave receiver ;
(2) A circuit for general reception ;
(3) A highly-selective receiving circuit ;
(4) A simple continuous-wave transmitter and wireless telephone.

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For descriptions of (1) and (2) see RADIO REVIEW, 1, pp. 181—183, and Abstract No. 170, January, 1920, respectively.

(3) is a two-valve amplifier, each valve having regenerative coupling with each circuit tuned.

(4) is a simple direct-coupled transmitter using a single valve, with anode and grid inductances in series in the aerial circuit.

152. THE SIX-STRING EINTHOVEN GALVANOMETER. (*Engineering*, 108, p. 255, August, 1919.)

An illustrated description.

153. AMPLIFIER DETECTOR FOR WIRELESS TELEGRAPHY. L. N. Brillouin and G. A. Beauvais. (*French Patent* 493332, March, 1916. Published August 6th, 1919.)

The leading features of this amplifier are: (1) that each valve simultaneously acts as amplifier and detector; (2) that the amplification is independent of the wavelength since no resonance is involved; (3) atmospherics and similar disturbances as well as extra strong signals are amplified less than weak signals. The circuits shown are those of an ordinary resistance-capacity coupled amplifier with a condenser in the grid circuit of the first valve.

154. THE EDISON EFFECT AND THE AUDION. (*Telegraph and Telephone Age*, p. 483, October, 1919.)

Refers to early experiments on the Edison effect and on flame conductivity.

155. THE THERMIONIC DETECTOR. H. J. van der Bijl. (*Popular Science Monthly*, 95, pp. 132—140, October, 1919.)

A popular account of the uses of the valve.

156. AUDION-CRYSTAL RECEIVER FOR DESTROYERS. (*Everyday Engineering Magazine*, 8, pp. 40—42, October, 1919.)

A description with illustrations of a receiver used on U.S. destroyers, adapted for reception of spark signals on a crystal, or on a single detecting (three-electrode) valve and provided with return-coupling for C.W. reception.

157. BATTLESHIP TYPE RECEIVER. (*Radio Amateur News*, 1, pp. 56—57, August, 1919.)

Illustrations and circuit diagrams of valve receiving apparatus.

158. MULTIPLE CONICAL LOOSE COUPLER. J. G. Merne. (*Radio Amateur News*, 1, pp. 67—68, August, 1919.)

A receiving tuner with the primary and secondary on coaxial conical formers.

159. HOW RADIO "SIGS." ARE PHOTOGRAPHED. (*Electrical Experimenter*, 7, p. 231, July, 1919.)

Describes an invention due to C. A. Hoxie, for the photographic reception and recording of wireless messages at 600-words per minute.

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160. "B" BATTERIES FOR VACUUM TUBES. W. P. Schulte. (*Everyday Engineering Magazine*, 7, pp. 364—365, September, 1919.)

Tests are described and curves given for the U.S. Navy type and Signal Corps type of H.T. batteries for use with valve receivers.

161. THE PROBLEMS OF VACUUM TUBE CIRCUITS. L. M. Clement. (*Everyday Engineering Magazine*, 7, pp. 367—369, September, 1919.)

A continuation of the previous articles describing multi-valve amplifiers. Views of Western Electric Company's instruments are given.

162. IMPROVEMENTS RELATING TO AUDIONS, LAMP RELAYS, OR AMPLIFYING APPARATUS. M. Latour. (*British Patent* 129660, October, 1916. Patent accepted July 24th, 1919.)

A further addition to Patent No. 127318, in which the receiving apparatus described in that patent is modified by first amplifying the received oscillations by means of a series of three electrode vacuum tubes with their circuits coupled through transformers with iron cores, then rectifying the amplified oscillations by any known apparatus, and finally amplifying the resulting low frequency current by a second series of three electrode vacuum tubes.

163. IMPROVEMENTS RELATING TO AUDIONS, LAMP RELAYS, OR AMPLIFYING APPARATUS. M. Latour. (*British Patent* 129661, October, 1916. Patent accepted July 24th, 1919.)

A further addition to Patent No. 127318. High frequency iron core transformers, employed in connection with vacuum tube amplifiers have the cross section of the iron in the parts of the core external to the coils greater than the cross section of the iron inside the coils. The coils described are wound in several layers with considerable spacing between the layers. The turns on each layer may further be spaced apart when necessary. This arrangement of the coils is adopted to reduce the electrostatic or capacity effects in the transformer windings.

164. IMPROVEMENTS RELATING TO AUDIONS, LAMP RELAYS, OR AMPLIFYING APPARATUS. M. Latour. (*British Patent* 130103, April, 1916. Patent accepted July 31st, 1919.)

Vacuum tube relay apparatus of the kind described in British Patent 127318, comprising a series of valves for amplifying in successive stages, is provided with a common battery for supplying the plate filament circuits of the various tubes, and a separate common battery for heating the filaments. The currents to be amplified are supplied through an iron-cored transformer to the grid of the first valve. The plate circuit of this valve acts through the second transformer on to the grid of the second tube, and so on. The plate circuit of the last tube acts through a transformer on to the output circuit.

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165. IMPROVEMENTS RELATING TO AUDIONS, LAMP RELAYS, OR AMPLIFYING APPARATUS. M. Latour. (*British Patent* 130012, November, 1916. Patent accepted July 31st, 1919.)

The receiving apparatus for wireless telegraphy and telephony comprises one or more three-electrode valves for high frequency amplification, a valve for rectifying or detecting the amplified oscillations, and one or more additional valves for amplifying the resulting low frequency current. The plates of all the tubes are connected to a common high tension battery. The specification describes the use of iron core transformers for all stages, radio frequency as well as low frequency. The grid circuit of the detecting valve includes a condenser shunted by a high resistance leak in the usual manner. The connection of a condenser between the grid and the filament of the last low frequency valve is claimed to reduce the tendency to arcing in the valve.

166. IMPROVEMENTS RELATING TO AUDIONS, LAMP RELAYS, OR AMPLIFYING APPARATUS. M. Latour. (*British Patent* 130022, December, 1916. Patent accepted July 31st, 1919.)

A further addition to British Patent 127318, dealing with a series of vacuum valve amplifiers connected in cascade with iron core inter-valve transformers. A tuned circuit is provided at each stage with the object of increasing the selectivity. The transformer cores are provided with air gaps, and the secondary of each inter-valve transformer is shunted by a condenser to give resonance to the desired frequency. The receiving aerial is not tuned to this frequency, so that oscillations set up therein by atmospherics are not reinforced by the amplifiers. A similar arrangement may be used for low frequency amplification by tuning the transformer secondary circuits to the note frequency instead of to the radio frequency.

167. A NEW INSTRUMENT FOR PRODUCTION OF UNDAMPED WAVES. (*Everyday Engineering Magazine*, 7, p. 366, September, 1919.)

An oscillating valve apparatus for 200 to 25,000 metres wavelength.

168. CRYSTAL DETECTORS. Société Française Radioélectrique. (*French Patent* 493454, July, 1916. Published August 9th, 1919.)

169. IMPROVEMENTS IN RELAY AMPLIFIERS FOR RADIOTELEGRAPHIC AND TELEPHONIC RECEPTION. A. J. B. Tauleigne. (*French Patent* 493489, July, 1916. Published August 9th, 1919.)

An electromagnetically operated microphonic relay magnifier.

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170. A NON-RADIATING WIRELESS RECEIVING CIRCUIT FOR THE RECEPTION OF DAMPED AND UNDAMPED WAVES. J. Scott-Taggart. (*Electrical Review*, 85, p. 614, November, 1919.)

In the receiving arrangement described two three-electrode valves are used. The first of these serves merely as a high-frequency amplifier and the second as a detector (Fig. 12). A return coupling is provided between the anode circuit of the second valve and its grid circuit for use in C.W.

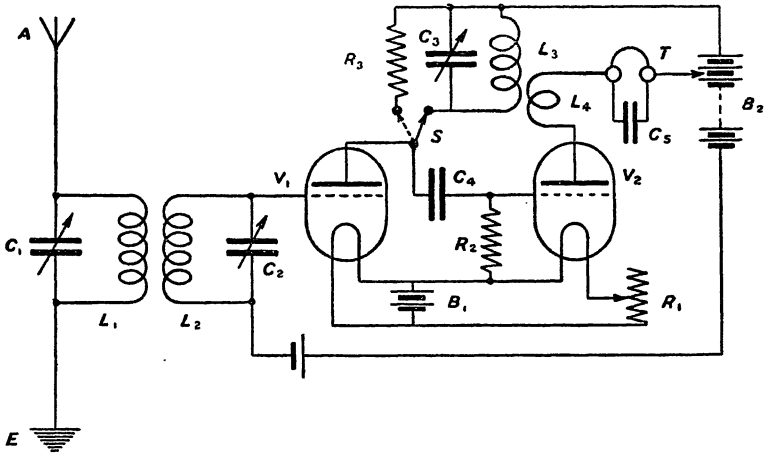

FIG. 12.

reception. For reception of spark signals the tuned circuit C_3 L_3 is replaced by a resistance R_3. When the arrangement is used for heterodyne reception only the valve V_2 should be oscillating while V_1 should prevent the return of oscillatory energy to the receiving aerial circuit A, E.

171. RECEIVING APPARATUS FOR WIRELESS TELEPHONY. Société Française Radioélectrique. (*French Patent* 493924, February, 1917. Published August 26th, 1919.)

For the reception of speech in a wireless telephone installation a local source of oscillation is used as in the usual manner of heterodyne reception. In order to avoid disturbance of the speech by the beat frequency the wavelength of the local oscillations should be adjusted to coincide as nearly as possible with that of the incoming signals. Best results are obtained when the two wavelengths are exactly the same.

172. RECEIVING ARRANGEMENT FOR WIRELESS TELEGRAPHY. Société Française Radioélectrique. (*French Patent* 493820, August, 1916. Published August 22nd, 1919.)

A wireless receiving arrangement in which the coupling between the detector and aerial circuits is effected by means of an iron-cored transformer.

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173. AN AERIAL ARRANGEMENT FOR WIRELESS TELEGRAPHY AND TELEPHONY. M. Latour. (*French Patent* 493063, October, 1919; published July 30th, 1919. *British Patent* 132101, October, 1917; published September 11th, 1919.)

The antenna current is divided between a number of earth plates by means of appropriate connections between these plates and the aerial circuit. The connections from the earth plates may be made to various points on the inductance in the aerial circuit or alternatively separate inductances may be joined in each earth lead. The object of the arrangement is to reduce the ohmic losses of the earth connection.

174. THE DISTANT CONTROL OF ELECTRICAL APPARATUS BY WIRELESS TELEGRAPHY. E. H. and K. A. Widegren. (*French Patent* 492928, December, 1916. Published July 25th, 1919.)

This control involves the continuous transmission of groups of electromagnetic waves in which the ratio of the length of the various groups to the intervals between them is variable at will in order to produce different effects at the receiver.

175. HIGH-FREQUENCY CURRENTS ON WIRES. J. O. Mauborgne (Signal Corps, U.S.A.). (*Journal Franklin Institute*, 188, pp. 91—93, July, 1919. *English Mechanic*, 110, p. 26, August, 1919, Abstract. *Post Office Electrical Engineers' Journal*, 12, pp. 153—155.)

The application of standard radio apparatus to multiplex wire telephony has been necessitated by the large number of wireless sets ordered for war-time requirements that are now lying idle. Using apparatus designed for ground stations of aircraft type for communication with aeroplanes, successful speech over existing telephone lines has been secured over sixty miles, using an input high-frequency current to the line of 60 milliamperes at 600,000 ~ (500 m. wavelength). The normal "radio" range of these sets was about ten miles.

176. THE THREE-ELECTRODE VALVE AND RADIO COMMUNICATIONS. (*La Nature*, 47, pp. 103—110, August, 1919.)

A general well-illustrated account of the various uses of a three-electrode valve for radio work. The general principle of its mode of operation is given, leading up to its employment as a detector, oscillation generator, amplifier. heterodyne receiver—or wireless telephone transmitter.

177. THE SPEED OF ELECTRICITY. A. E. Kennelly. (*Wireless Age*, 6, p. 11, August, 1919.)

A general account of Maxwell's theory, and dealing with the speeds of propagation of free electromagnetic waves, and of waves guided along wires or along the conducting surfaces of the earth or sea.

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178. ON THE TRANSMISSION OF SPEECH BY LIGHT. A. O. Rankine. (*Proceedings of the Physical Society of London*, 31, pp. 242—268, August, 1919. *Electrical Review*, 85, p. 81, Abstract.)

This paper describes a lengthy research carried out for the Admiralty Board of Invention and Research. It deals chiefly with the modulation of a fixed beam of light in accordance with the sound or speech waves to be transmitted. The transmitter specially developed in this research consists in principle of two parallel grids through which the light is passed. Between the two grids the beam is reflected at a small mirror mechanically connected to the transmitting diaphragm. In this manner the image of the first grid is moved over the second so that more or less light is emitted from the second grid in accordance with the speech form. The grids were 7 inches diameter and the bars and spaces each $\frac{1}{10}$ inch wide. A selenium receiver was used, and a speaking range of $1\frac{1}{2}$ miles has been secured. The articulation is particularly good.

In the discussion on the paper other methods of modulation were dealt with, together with some considerations of the efficiency of the method.

179. ON THE USE OF THE TRIODE VALVE IN MAINTAINING THE VIBRATION OF A TUNING FORK. W. H. Eccles. (*Proceedings of the Physical Society of London*, 31, p. 269, August, 1919.)

2. Review of Books.

A GUIDE TO THE STUDY OF THE IONIC VALVE, showing its development and application to Wireless Telegraphy and Telephony. By W. D. Owen, A.M.I.E.E. (London: *Sir Isaac Pitman & Sons, Ltd.* Pp. vii. + 59. Price 2*s.* 6*d.* net.)

This little booklet is a series of brief notes upon the various aspects of the valve, and upon the various uses to which the valve may be put, and is admitted to be such by the author who states in the Preface that they "were originally compiled for the guidance of a little circle of enthusiasts whose interest in the ionic valve was stimulated by repeated references in the technical Press to its numerous applications and wonderful achievements." To any one unacquainted with wireless work, but engaged in other branches of electrical or physical science and therefore familiar with ordinary electrical nomenclature this booklet may appeal, but to the true seeker after knowledge of valve work its scope is too limited and the treatment far too brief. In short its function is to state simply what a valve is and what it can do rather than to contribute new matter to the knowledge of the subject —as an instance, the whole fields of "Continuous Wave Telegraphy" and of

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"Reception of Continuous Waves," are discussed in two "chapters" of about 175 words each. The title of the booklet appears to be rather too ambitious and comprehensive.

A few criticisms may be made against the clarity of some of the statements —for example on pp. 3, 19, 30, 35 and 38, but otherwise the treatment is clear, and a useful feature is a number of references to fuller literature on the subject.

P. R. C.

ALTERNATING CURRENT WORK: An Outline for Students of Wireless Telegraphy. By A. Shore, A.M.I.E.E. (London: *The Wireless Press, Ltd.* Pp. ix. + 163. Price 3*s.* 6*d.* net.)

Correspondence.

THE OSCILLATING TRIODE.

TO THE EDITOR, THE "RADIO REVIEW."

SIR,—Mr. R. C. Clinker in his letter to you of the 1st inst. does not call into question the truth of the expression I used, but merely prefers to throw it into a slightly different form.

There are of course two ways of regarding the amplification produced by a valve—from either the standpoint of E.M.F. or current. The latter is the simpler at first sight, though for many purposes the former is preferable.

As Mr. Clinker points out it is the *current* factor of amplification which is implied in my remarks.

R. WHIDDINGTON.

The University, Leeds,
November 20th, 1919.

TO THE EDITOR, THE "RADIO REVIEW."

SIR,—Permit me to support Mr. R. C. Clinker's plea that the amplification parameter of a triode should be expressed as the simple ratio of the E.M.F. liberated in the anode circuit to that applied in the grid circuit in the ordinary mode of employment. I urge this, not only because it gives a figure of merit that is independent of the nature of the apparatus connected to the electrodes of the tube, but also because it is nearer the physics of the matter. The physics may, I think, be summarised as follows:—When one applies say 100 volts between the hot filament and the anode of a small triode the moving electrons between cathode and anode create by their mutual repulsion a back E.M.F. of, say, 50 volts which is rather analogous to the back E.M.F. of polarisation in electrolysis; if now one increases the potential of the grid relative to the filament by say 1 volt one finds that, say, 10 volts of the back E.M.F. are cancelled. Therefore 10 volts of the anode battery are

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liberated for propelling current. The number 10 is in this case the voltage factor of the tube, sometimes called the amplification factor. I prefer the term "voltage factor" because we may some day find step-down tubes useful, though at present only step-up tubes are widely used. Amplification is a word only applicable strictly to step-up triodes.

While writing I should like to refer to the choice of a symbol for the voltage factor. Langmuir used k, but as in wireless literature k has always been used for the co-efficient of coupling I have myself used the letter g. Sometimes m is used but, again, m is the universal symbol for the mass of an electron and therefore appears in that sense in the theory of all ionic tubes. The International Electrotechnical Commission have suggested that mere numbers should be represented by lower-case Greek letters. Almost the only Greek letters not allocated by the Electrotechnical Commission or the Physical Society of London to important electrical quantities are Upsilon, capital (Υ), and lower case (υ), Xi, lower case (ξ), Nu (ν), and Pitau (ϖ).

It would be interesting to have your readers' views upon the best symbol for this most important parameter of the triode.

W. H. ECCLES.

City and Guilds Technical College,
Finsbury, E.C. 2.
December 9th, 1919.

ERRATA.

(NOTE.—*Any notices of errata that may be found necessary from time to time will always be inserted in this position in the* REVIEW.)

Page 77 (November), *line* 2, *the formula should read,*

$$\frac{\partial i_a}{\partial e_g} = g\frac{\partial i_a}{\partial e_a}.$$

Page 104, *line* 24, *for* "positive electrons" *read* "positive ions."

Page 104, *line* 32, *for* "high cathode" *read* "high temperature cathode."

Page 122 (December). Fig. 13. *The ordinate scale should be marked* γ_s *not* γ *; and the formula beneath this figure should read,*

$$\gamma_s = \tfrac{1}{2}\tan^{-1}\left[\tan\phi \,.\, \tanh\frac{\Delta\phi}{2\pi}\right]$$

Page 132, *line* 3, *should read,*

$$\frac{di_a}{de_l} = \frac{3}{2}A'ye_l^{\frac{1}{2}}.$$

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FEB

THE RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. 1 FEBRUARY, 1920 NO. 5

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The Physical Society of London Exhibition.

Review of Radio Literature:
Abstracts of Articles.
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THE
RADIO REVIEW

VOL. I FEBRUARY, 1920 NO. 5

A Method of Direction Finding of Wireless Waves

And its Applications to Aerial and Marine Navigation.*

By Capt. JAMES ROBINSON, R.A.F., M.Sc., Ph.D.

SUMMARY

1. Introduction.
2. Description of Method.
3. Sensitiveness of D.F. Coils.
4. Ambiguity.
5. General Application of the Method.
6. D.F. on Aircraft.
7. Design of Coils for any Wavelength.
8. Types of Coil.
9. Appendix.

1. INTRODUCTION

THE principal methods hitherto used for finding the direction of wireless waves make use of the well-known properties of a loop, that, when the plane of the loop is perpendicular to the direction of the waves, no energy is absorbed, and, when parallel to the direction of the waves, the maximum amount of energy is absorbed. In order to find the direction most accurately, use is made of the fact that the rate of variation of the energy

* Paper received August, 1919.

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absorbed is greatest near the minimum. The loop is swung through the minimum position until signals can just be heard on either side. The positions where the signals are just audible are noted, and the position half way between taken as the indication of the minimum. The variation of intensity of signal is so slow at the maximum that it is impossible to fix the maximum within 5° or 10°.

The minimum method is used in two well-known cases :—

(*a*) Where the aerial consists of a single loop of one or more turns, the loop being capable of rotation about a vertical axis.

(*b*) In the Bellini Tosi method, where two fixed aerials at right angles are used, and where the moving part is a small coil inside an instrument known as a radiogoniometer.

The accuracy of such a method depends on various things, one of which is the strength of signal. For very weak signals the region of silence may be large, and at times it may exceed 90°. In such a case, the positions where the signal is just audible have to be estimated very accurately, in order that a reliable determination of the minimum can be obtained. Again, it is often difficult to guarantee to within a few degrees just where the signal is audible. External noises have great influence on the determination of the positions where the signal is just audible, and this becomes serious in cases where the disturbances vary in intensity in different directions, as is often the case with atmospherics, and also on aircraft where there is a lot of external noise.

Hence it seems advisable to have a method for finding direction where the coils can be placed actually on the position which indicates the bearing, thus avoiding the necessity of having to determine two positions where signals are just audible. This will again be increased in importance if the signal can be heard whilst the bearing is being taken. The method about to be described fulfils these wants.

2. Description of the Method

The method will first be described for the case of aerial coils which can be rotated about a vertical axis. Two coils at right angles are used, being rigidly attached so as to be rotatable together. Obviously, if one coil is at the minimum position for incoming waves, the other will be at the maximum. In order that signals may be heard whilst taking a bearing, the coils are

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placed so that one coil is near its maximum. To do this, arrangements are made so that this coil can be used alone. We have seen that the maximum position of this coil, which we shall call the main coil, can only be roughly determined in this way. When, however, the other coil, called the auxiliary coil, is introduced, there will be a change in intensity of signal, unless this coil is at its zero position. If there is such a change of intensity the system is rotated slightly until the signals are of equal intensity, when the pointer will indicate the direction of the incoming waves. In practice, however, it is preferable not to change from main coil to main and auxiliary coil, but to proceed as follows. The maximum of the main coil is determined approximately. The auxiliary coil is then introduced and its connections reversed a few times, thus adding or subtracting the E.M.F. of the auxiliary coil to or from the E.M.F. of the main coil. When the auxiliary coil is at its minimum position the reversals will produce no change in intensity of signal.

One method of applying this system is shown in Fig. 1.

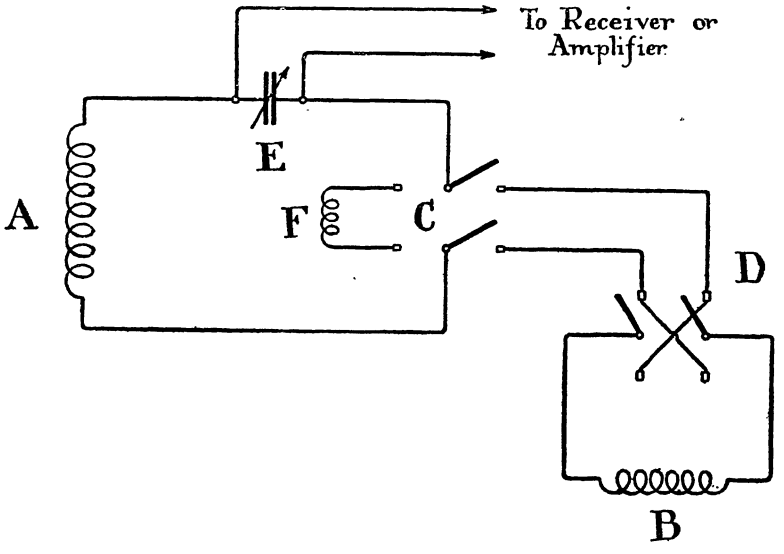

FIG. 1.

A is the main, and B the auxiliary coil. C is a change over switch, so that either the main coil alone, or the main and auxiliary in series can be used. D is a reversing switch to reverse the

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connections of the auxiliary coil. E is a tuning condenser from the terminals of which leads are taken to the receiver or amplifier. It is convenient to arrange that there shall be no change of tuning when the auxiliary coil is introduced. For this purpose a balancing inductance, F, is used of the same inductance as the auxiliary coil, but of small dimensions, so that it picks up a negligible amount of energy from the waves.

The method of using this to find a bearing is as follows :— Contact is made with the change over switch, C, to the left. The signals are tuned in by the condenser, E, and the coils rotated to obtain the approximate maximum position of the aerial coil, A. The change over switch, C, is now placed to make contact on the right, and the reversing switch, D, moved from side to side a few times. If the signals are of different intensity, the aerial coils are moved slightly until a position is found where the signal strength is the same on reversal of the auxiliary coil. Then the direction of the incoming waves is given by the plane of the main coil.

An alternative way of applying this method is shown in Fig. 2.

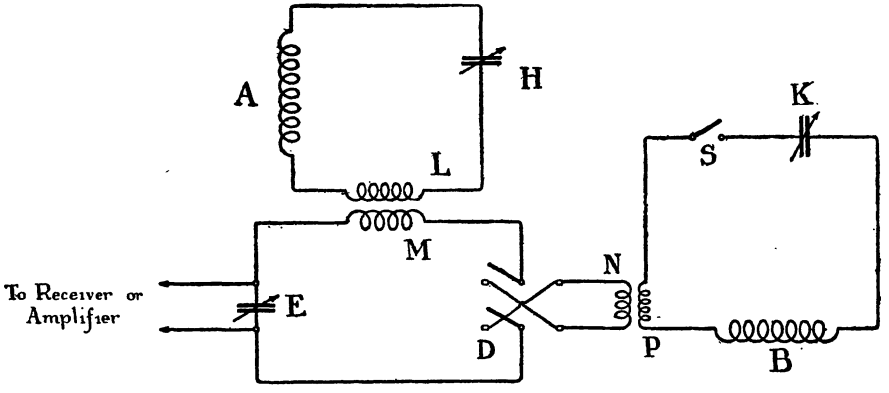

FIG. 2.

In this arrangement each aerial coil is in its own tuned circuit. The effects from the main and auxiliary coils, A and B, are combined in a circuit, MNDE, by means of the coupling coils, LM and NP.

The effects from the auxiliary coil are reversed by the reversing switch, D. In order that the main coil alone can be used to obtain its approximate maximum a make-and-break switch, S, is inserted in the circuit of the auxiliary coil, B. This method is

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not so simple as that in Fig. 1, because of the necessity of having to use three tuning condensers. It should be noted, however, that there is no necessity to have extremely accurate tuning of any of the condensers, as is the case with the Bellini Tosi system.

3. SENSITIVENESS OF D.F. COILS.

By this system of direction-finding, the coils are placed in a definite position which indicates the direction of the incoming waves. As it is necessary to judge when signals are of equal strength, it may be presumed that there is a small angle in which it is difficult to decide whether the signals are of equal intensity or not. The magnitude of this angle determines the sensitiveness of the system, and we shall now proceed to consider the conditions controlling the sensitiveness.

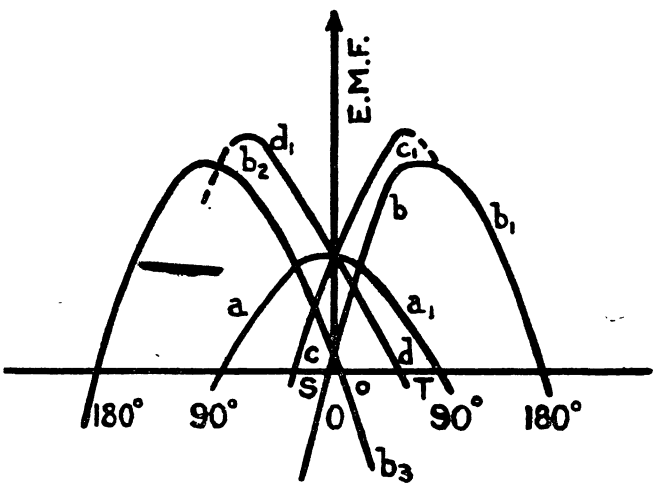

FIG. 3.

In Fig. 3 is shown the E.M.F. produced in the coils from electromagnetic waves from some constant source, for various orientations of the coils. The curve aa_1 shows the E.M.F. for the main coil, this being represented so as to be a maximum for 0°, and minimum or zero for ± 90°. This curve is a curve of trigonometrical form.

Curve bb_1, also a curve of trigonometrical form, shows the E.M.F. for various orientations of the auxiliary coil, the maximum now being at ± 90° and the zero value at 0°. When the connections of the auxiliary coil are reversed the E.M.F. curve becomes b_2b_3.

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When the main and auxiliary coils are used together we get curves cc_1 or dd_1, according to whether the one or other auxiliary curves, bb_1 or b_2b_3, is used.

Main coil curve aa_1 is represented by $y_1 = a \cos \theta$.
Auxiliary coil curve bb_1 is represented by $y_2 = b \sin \theta$.
Combined curve cc_1 is $Y_1 = a \cos \theta + b \sin \theta$.
Combined curve dd_1 is $Y_2 = a \cos \theta - b \sin \theta$.

These curves cross when

$$Y_1 = Y_2,$$
$$i.e., \; a \cos \theta + b \sin \theta = a \cos \theta - b \sin \theta,$$
$$i.e., \text{ for } 2b \sin \theta = 0,$$
$$i.e., \; \theta = 0,$$

which is for the maximum of the main coil and minimum of the auxiliary coil. The sensitiveness of the system is determined by the angle $2d\theta$ about the position $\theta = 0$, in which the ear cannot determine any difference in intensity, this angle $2d\theta$ being composed of $d\theta$ on each side of the maximum position of the main coil. At a position $d\theta$ from the position of equal signals we have

$$Y_1 = a \cos d\theta + b \sin d\theta.$$
$$Y_2 = a \cos d\theta - b \sin d\theta.$$

The difference in E.M.F. is $Y_1 - Y_2 = Y_3$, and the mean E.M.F. is $\frac{Y_1 + Y_2}{2} = Y_4$.

The ratio $\frac{Y_3}{Y_4}$, *i.e.*, the ratio of the difference in E.M.F. to the mean E.M.F. is intimately bound up with the sensitiveness

$$\frac{Y_3}{Y_4} = \frac{2b \sin d\theta}{a \cos d\theta},$$

which is approximately $2\frac{b}{a} \sin d\theta$.

The term $\frac{b}{a}$ is the ratio of the maximum E.M.F.'s produced in the auxiliary and main coils. This ratio we shall call k. Under normal conditions k is equal to the ratio of the area-turns of the auxiliary and main coils, where by area-turns of a coil is meant the summation of the areas of each turn of the coil.*

Then we have $\frac{Y_3}{Y_4} = 2k \sin d\theta$.

* See below for evidence to support this view.

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Taking $d\theta$ as some small angle, say 1°, the ratio $\frac{Y_3}{Y_4}$ can easily be calculated for various values of k. The following table contains some values :—

k = ratio $\frac{\text{Auxiliary}}{\text{Main}}$ Area-turns.	Per cent. change of E.M.F. for 1° = $2k \sin 1° \times 100$.	k = ratio $\frac{\text{Auxiliary}}{\text{Main}}$ Area-turns.	Per cent. change of E.M.F. for 1° = $2k \sin 1° \times 100$.
$\frac{1}{4}$	0·9 per cent.	1·5	5·2 per cent.
$\frac{1}{3}$	1·2 ,,	2·0	7·0 ,,
$\frac{1}{2}$	1·75 ,,	2·5	8·7 ,,
$\frac{3}{4}$	2·65 ,,	3·0	10·5 ,,
1	3·5 ,,	5·0	17·5 ,,
		10·0	35·0 ,,

Taking any particular value of k, say, $k = 2{\cdot}5$, we find that, when 1° away from the true position, there is an 8·7 per cent. change in E.M.F. on reversal of the auxiliary coil. Without going into the difficult problem of what percentage change of intensity of sound the ear can determine, it is found in practice with the coils that have been used in the services that this 8·7 per cent. change of E.M.F. can be distinguished. Thus, for the ratio of auxiliary to main area-turns = 2·5, there is no doubt in the observer's mind that the signals are of different intensity when he is 1° away from the true position.

For such a system of coils the sensitiveness is such that there is certainty of being within 1° of the correct position. Naturally, training is of great importance, and trained operators can be certain of even greater accuracy.

For a ratio $k = 10$ there is 35 per cent. change of E.M.F. when 1° from the correct position, and the system has been found, in practice, to be sensitive to $\frac{1}{4}$°.

This method thus shows how it is possible to determine the direction of incoming waves with any accuracy required up to what has so far been found to be the highest practicable accuracy of $\frac{1}{4}$°.

(To be concluded.)

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Damped Oscillations in Coupled Circuits*

By G. BRAMWELL EHRENBORG

THE starting-point of a mathematical discussion of the phenomena in two coupled circuits is a system of two linear differential equations of the second order. Each of these equations belongs to one circuit, in the sense that the majority of the terms in it refer to the voltage (or current) in that circuit; but there are also terms, which may conveniently be called cross terms, which are derived from the voltage in the other circuit, and which constitute the mathematical formulation of the effect of the latter circuit on the former. If the cross terms were absent, the integration of the differential equations would of course depend on the solution of quadratic equations. Owing to the presence of the cross terms, the two differential equations must be combined so as to form a single differential equation of the fourth order, the integration of which depends on the solution of a biquadratic. If the resistances are so small that their squares can be neglected, a manageable solution of the biquadratic can be found. This has been done by various writers; two of the more recent papers on the subject have been published in the *Jahrbuch der Drahtlosen Telegraphie*, one by Macků (Vol. 3, p. 329) and the other by John Stone Stone (Vol. 7, p. 8). The former contents himself with solving the biquadratic, while the latter carries out the integration completely.

There is, however, another method of dealing with the problem. The fact that there is a biquadratic to solve instead of two quadratics was seen to be due to the presence of the cross terms, and it therefore seems worth while to try to effect such a change of variables that in the transformed system of differential equations the cross terms are as small as possible; if the damping is small, one would naturally try to arrange matters so that the only cross terms are damping terms. Transformations of this nature have been known and studied for well over a century, but as they are hardly ever dealt with outside the pages of advanced textbooks on dynamics and other publications entirely devoted to the interests of pure mathematicians, they have not received the attention they merit from radio engineers. The only instance known to the writer in which they have been applied to the problem now under discussion is in a paper by Louis Cohen (*Jahrbuch der Drahtlosen Telegraphie*, Vol. 2, p. 448), and in that article the author unfortunately chooses a transformation which would be suitable if the square of the condenser voltage were negligible in comparison with the square of the voltage drop in the resistance, whereas the exact opposite is what usually occurs in practice.

The object of the present paper is to apply the above-mentioned method to the study of the free oscillations in two circuits electromagnetically coupled, that transformation being chosen which is most nearly in accord with practical conditions. It will be found that the biquadratic can then in

* Paper received in final form, October 21st, 1919.

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general be broken up into two quadratic factors without any serious error. There are other advantages also. It will be at once apparent that if a certain relation holds between the resistances and the capacities, the error vanishes so that the solution obtained is exact. Further, an estimate can easily be made of the magnitude of the error when this relation no longer holds. Finally, the evaluation of the integration constants is a far less laborious process than would have been the case if no change of variables had been carried out.

Consider two circuits, each of which contains a condenser in series with one of the windings of an oscillation transformer and (possibly) with some other inductance as well. In the first circuit let the total self-inductance be L_1, the capacity of the condenser C_1, the resistance R_1, the potential difference on the condenser terminals v_1 and the current i_1. Let the corresponding quantities in the second circuit be L_2, C_2, R_2, v_2 and i_2 respectively, and let the mutual inductance between the two circuits be M. All inductances, capacities and resistances are assumed to be constant. If we make the convention that the current is positive when it flows from the positive condenser terminal through the metallic part of the circuit to the negative terminal, we have

$$i_1 = -C_1 \frac{dv_1}{dt}; \quad i_2 = -C_2 \frac{dv_2}{dt}.$$

The equations of the two circuits are

$$i_1 R_1 = -L_1 \frac{di_1}{dt} - M \frac{di_2}{dt} + v_1;$$

$$i_2 R_2 = -L_2 \frac{di_2}{dt} - M \frac{di_1}{dt} + v_2;$$

If we express the currents in terms of the voltages and introduce the fluxional notation (*i.e.*, $\dot{v}_1 = \frac{dv_1}{dt}$, $\ddot{v}_1 = \frac{d^2v_1}{dt^2}$, etc.), these equations transform into

$$L_1C_1\ddot{v}_1 + R_1C_1\dot{v}_1 + v_1 + MC_2\ddot{v}_2 = 0$$
$$MC_1\ddot{v}_1 + L_2C_2\ddot{v}_2 + R_2C_2\dot{v}_2 + v_2 = 0$$

It is convenient for future work to employ the following notation :—

$$L_1C_1 = u_1; \quad L_2C_2 = u_2; \quad \frac{M}{\sqrt{L_1L_2}} = k; \quad \frac{v_1}{\sqrt{L_1}} = v_1'; \quad \frac{v_2}{\sqrt{L_2}} = v_2';$$

Then the equations become

$$\left.\begin{aligned} u_1\ddot{v}_1' + R_1C_1\dot{v}_1' + v_1' + ku_2\ddot{v}_2' = 0 \\ ku_1\ddot{v}_1' + u_2\ddot{v}_2' + R_2C_2\dot{v}_2' + v_2' = 0 \end{aligned}\right\} \quad \ldots\ldots \quad (1)$$

The constant k is called the coefficient of coupling between the two circuits ; it is always less than the coefficient of coupling of the oscillation transformer considered by itself, since the self-inductance of each of the windings is necessarily less than the total self-inductance of the circuit of which it forms a part. k is therefore always less than unity, but it may yet be far from

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negligible, and it is the presence of the terms of which k is a factor which causes the difficulty of integrating the two equations. The difficulty is surmounted in the following way :—

Multiply the first equation by μ_1 and the second by μ_2 and add; we obtain

$$(\mu_1 u_1 + \mu_2 k u_1)\ddot{v}_1' + (\mu_1 k u_2 + \mu_2 u_2)\ddot{v}_2' + \mu_1 R_1 C_1 \dot{v}_1' + \mu_2 R_2 C_2 \dot{v}_2' + \mu_1 v_1' + \mu_2 v_2' = 0 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Now introduce a new variable ξ such that

$$\left.\begin{aligned}(\mu_1 u_1 + \mu_2 k u_1)v_1' + (\mu_1 k u_2 + \mu_2 u_2)v_2' &= \xi \\ \mu_1 v_1' + \mu_2 v_2' &= \lambda\xi\end{aligned}\right\}$$

where λ is a constant to be determined.

The last two equations will be consistent for all values of v_1' and v_2' if

$$\left.\begin{aligned}\left(u_1 - \frac{1}{\lambda}\right)\mu_1 + k u_1 \mu_2 &= 0 \\ k u_2 \mu_1 + \left(u_2 - \frac{1}{\lambda}\right)\mu_2 &= 0\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

If these equations are to have any other solution than $\mu_1 = \mu_2 = 0$ (which is of no value to us), we must have

$$\begin{vmatrix} u_1 - \frac{1}{\lambda} & k u_1 \\ k u_2 & u_2 - \frac{1}{\lambda} \end{vmatrix} = 0, \text{ or } \left(\frac{1}{\lambda} - u_1\right)\left(\frac{1}{\lambda} - u_2\right) = k^2 u_1 u_2 \quad . \quad . \quad (4)$$

This is a quadratic in $\frac{1}{\lambda}$ which, written in the usual form, reads

$$\frac{1}{\lambda^2} - (u_1 + u_2)\frac{1}{\lambda} + (1 - k^2)\, u_1 u_2 = 0.$$

If this equation is satisfied when $\lambda = p^2$ and when $\lambda = q^2$, we know from the theory of quadratic equations that

$$\left.\begin{aligned}\frac{1}{q^2} + \frac{1}{p^2} &= u_1 + u_2 \\ \frac{1}{p^2 q^2} &= (1 - k^2)\, u_1 u_2\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

On solving the quadratic we find

$$\left.\begin{aligned}\frac{1}{p^2} &= \frac{1}{2}\left(u_1 + u_2 - \sqrt{(u_1 - u_2)^2 + 4k^2 u_1 u_2}\right) \\ \frac{1}{q^2} &= \frac{1}{2}\left(u_1 + u_2 + \sqrt{(u_1 - u_2)^2 + 4k^2 u_1 u_2}\right)\end{aligned}\right\} \quad . \quad . \quad . \quad (6)$$

If, as is customary, we take $\sqrt{(u_1 - u_2)^2 + 4k^2 u_1 u_2}$ to mean the positive square root of $(u_1 - u_2)^2 + 4k^2 u_1 u_2$, we see that $\frac{1}{p^2}$ is always less than $\frac{1}{q^2}$. If k were $= 1$, $\frac{1}{p^2}$ would be zero, but as k is always less than that, $\frac{1}{p^2}$ is always

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positive. A little consideration will show that both u_1 and u_2 lie between $\frac{1}{q^2}$ and $\frac{1}{p^2}$, and by writing the first of the equations (5) in the form $\frac{1}{q^2} - u_1 = u_2 - \frac{1}{p^2}$ we see that $\frac{1}{q^2}$ is greater than u_1 by the same amount as $\frac{1}{p^2}$ is less than u_2. When $k = 0$, $\frac{1}{p^2}$ = the lesser of u_1 and u_2, and $\frac{1}{q^2}$ = the greater.

Either of the two roots when substituted in equations (3) will give us a value of the ratio $\frac{\mu_1}{\mu_2}$ which will make the two equations giving ξ in terms of v_1' and v_2' consistent. The actual values of μ_1 and μ_2 are indeterminate, but that is a matter of no importance to us, for we see that the effect of multiplying each of these quantities by a given constant is to multiply equation (2) by the same constant, a process which makes it neither easier nor more difficult to integrate.

When $\lambda = p^2$, the first of equations (3) gives us $\frac{\mu_1}{\mu_2} = -\frac{ku_1}{u_1 - \frac{1}{p^2}}$, and the second, $\frac{\mu_1}{\mu_2} = -\frac{u_2 - \frac{1}{p^2}}{ku_2}$; we see at once that these two values of the ratio are equal, since $\frac{1}{p^2}$ is a root of (4). For future work we shall make use of the former of the two values, and we shall take the actual values of μ_1 and μ_2 to be respectively ku_1 and $-\left(u_1 - \frac{1}{p^2}\right)$ when $\lambda = p^2$.

When λ has this value let ξ have the value x, and when $\lambda = q^2$ let $\xi = y$. Then the equation $\mu_1 v_1' + \mu_2 v_2' = \lambda\xi$ becomes in these two cases respectively

$$\left.\begin{aligned} ku_1 v_1' - \left(u_1 - \frac{1}{p^2}\right) v_2' &= p^2 x \\ ku_1 v_1' - \left(u_1 - \frac{1}{q^2}\right) v_2' &= q^2 y \end{aligned}\right\} \quad \ldots\ldots \quad (7)$$

if we take $\mu_1 = ku_1$ and $\mu_2 = -\left(u_1 - \frac{1}{q^2}\right)$ when $\lambda = q^2$.

We now return to equation (2) and write down the two forms it takes when $\lambda = p^2$ and $\lambda = q^2$. These are

$$\ddot{x} + ku_1 R_1 C_1 \dot{v}_1' - \left(u_1 - \frac{1}{p^2}\right) R_2 C_2 \dot{v}_2' + p^2 x = 0$$

$$\ddot{y} + ku_1 R_1 C_1 \dot{v}_1' + \left(\frac{1}{q^2} - u_1\right) R_2 C_2 \dot{v}_2' + q^2 y = 0$$

To complete the transformation to the new variables we simply have to solve equations (7) and substitute the values of v_1' and v_2' thereby obtained in the above two equations. We find

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$$\left.\begin{aligned} v_1' &= \frac{\frac{1}{q^2} - u_1}{\left(\frac{1}{q^2} - \frac{1}{p^2}\right) k u_1} p^2 x + \frac{u_1 - \frac{1}{p^2}}{\left(\frac{1}{q^2} - \frac{1}{p^2}\right) k u_1} q^2 y \\ v_2' &= -\frac{1}{\frac{1}{q^2} - \frac{1}{p^2}} p^2 x + \frac{1}{\frac{1}{q^2} - \frac{1}{p^2}} q^2 y \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (8)$$

Now the differential equations become

$$\left.\begin{aligned} \ddot{x} + 2\alpha\dot{x} + p^2 x + f\dot{y} &= 0 \\ g\dot{x} + y + 2\beta\dot{y} + q^2 y &= 0 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where

$$\left.\begin{aligned} f &= \frac{u_1 - \frac{1}{p^2}}{\frac{1}{q^2} - \frac{1}{p^2}} (R_1C_1 - R_2C_2)\, q^2 \\ g &= \frac{\frac{1}{q^2} - u_1}{\frac{1}{q^2} - \frac{1}{p^2}} (R_1C_1 - R_2C_2)\, p^2 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$\left.\begin{aligned} \alpha &= \frac{\left(\frac{1}{q^2} - u_1\right) R_1C_1 + \left(u_1 - \frac{1}{p^2}\right) R_2C_2}{2\left(\frac{1}{q^2} - \frac{1}{p^2}\right)} p^2 \\ \beta &= \frac{\left(u_1 - \frac{1}{p^2}\right) R_1C_1 + \left(\frac{1}{q^2} - u_1\right) R_2C_2}{2\left(\frac{1}{q^2} - \frac{1}{p^2}\right)} q^2 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (11)$$

It is convenient to express α as the sum of two terms, one of which depends on $R_1C_1 + R_2C_2$ and the other on $R_1C_1 - R_2C_2$, and similarly for β. If we write R_1C_1 in the form $\frac{R_1C_1 + R_2C_2}{2} + \frac{R_1C_1 - R_2C_2}{2}$ and R_2C_2 in the form $\frac{R_1C_1 + R_2C_2}{2} - \frac{R_1C_1 - R_2C_2}{2}$, and if we make use of the first of equations (5), we find

$$\left.\begin{aligned} \alpha &= \frac{R_1C_1 + R_2C_2}{4} p^2 - \frac{R_1C_1 - R_2C_2}{4\left(\frac{1}{q^2} - \frac{1}{p^2}\right)} (u_1 - u_2) p^2 \\ \beta &= \frac{R_1C_1 + R_2C_2}{4} q^2 + \frac{R_1C_1 - R_2C_2}{4\left(\frac{1}{q^2} - \frac{1}{p^2}\right)} (u_1 - u_2) q^2 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (12)$$

(To be continued.)

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The High-Frequency Resistance of Wires and Coils.*

By Prof. G. W. O. HOWE, D.Sc., M.I.E.E.

THE last five years have seen a remarkable development of the application of high-frequency currents to telegraphy and telephony. In all cases, it is a matter of importance to be able to calculate or, at least, to predict the losses occurring in coils when carrying high-frequency currents.

No attempt is made to deal exhaustively with the subject in this paper. An explanation is given of the principles involved and it is shown how these principles can be applied to the calculation of the resistance of wires and coils.

STRAIGHT ROUND WIRE.

In a previous paper † the author has shown how the well-known telephone transmission formulæ may be used to calculate the skin effect in many cases. It is there shown that in a solid round wire carrying a current of such a high frequency that the penetration is small, the ratio of the high-frequency resistance R_f to the steady current resistance R_o is given by the formula

$$\frac{R_f}{R_o} = \pi r \left(\sqrt{\frac{f\mu}{10^9\rho}}\right) + 0{\cdot}25$$

where r is the radius of the wire, f the frequency, μ the permeability, and ρ the specific resistance.

PARALLEL STRIPS.

When it is desired to keep the inductance of a circuit as low as possible, parallel strips placed close together are frequently employed. If the frequency is so high that the current density at the back of the strips is practically zero, this is the simplest of all skin-effect calculations; it is considered in detail on pages 473 to 475 of the previous paper.† The resistance and losses are shown to be the same as if the total current were distributed uniformly over a layer of depth t where $t = \frac{1}{2}\pi\sqrt{\frac{10^9\rho}{f\mu}}$.

For copper at a frequency of a million, $t = 0{\cdot}066$ mm. If the frequency and the thickness of the strips are such that the current penetrates appreciably throughout the whole cross-section, the problem is analogous to that of the telephone line when the current is not attenuated to zero before arrival at the far end, in which case a reflected wave is superposed upon the forward wave. The formulæ for this case are well known and are used daily by telephone and alternating-current power-transmission engineers. They are employed on pages 478 and 479 of the previous paper† to calculate the current

* Abstract of paper read before the Institution of Electrical Engineers (Wireless Section), on December 19th, 1919.

† "The Application of Telephone Transmission Formulæ to Skin-Effect Problems," *Journal Inst. Electrical Engineers*, 54, p. 473, 1916.

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density at different depths and the resultant resistance. It is shown that $\frac{R_f}{R_o} = \frac{\beta\tau}{\gamma}$ where $\beta = 2\pi\sqrt{\frac{f\mu}{10^9\rho}}$, τ = the thickness of the strip, and $\gamma = \frac{\cosh 2\beta\tau - \cos 2\beta\tau}{\sinh 2\beta\tau + \sin 2\beta\tau}$.

For small values of $2\beta\tau$ that is, for low frequencies or very thin strips, this reduces to

$$\frac{R_f}{R_o} = 1 + \frac{2}{3} \cdot \frac{(2\beta\tau)^4}{5!}$$

which for copper may be written $R_f/R_o = 1 + 47{\cdot}5\ (\tau\sqrt{f})^4 \cdot 10^{-6}$.

The value of R_f/R_o for any value of $\beta\tau$ can be read directly off the curve in Fig. 1.

SINGLE-LAYER CYLINDRICAL COILS.

Coils wound with Rectangular Wire.—In the previous paper the author has shown that the resistance of a long coil closely wound with a single layer of square or rectangular wire is given accurately by the same formula as that already found for the parallel strips, viz.

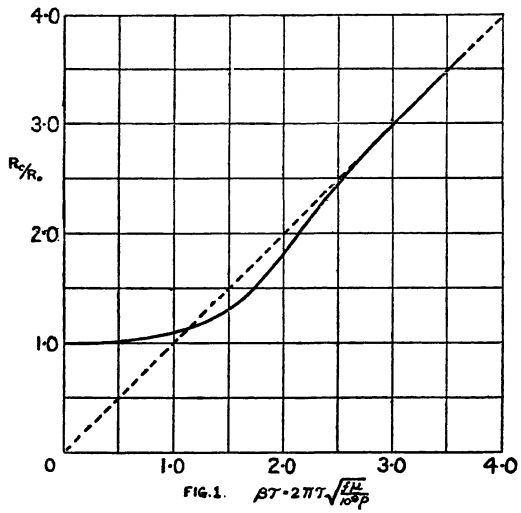

FIG. 1.

$$R_c = R_o \frac{\beta\tau}{\gamma},$$

where τ is the radial thickness of the wire. The values of R_c/R_o are plotted in Fig. 1 against values of $\beta\tau$.

If there is a small space between adjacent turns, the magnetic field within the conductor and in the spaces between the turns will still be approximately linear and parallel to the axis of the coil, but for a given current density the magnetic flux density will be reduced. The same result would be caused by a decrease in the permeability and either would lead to an increased penetration. If the wire has a square section of side τ cm. and if S is the number of turns per cm., $S\tau$ is the fraction of the axial length occupied by the conductor, the remainder being occupied by insulation or air space. The penetration would be the same if the turns were close together, but the permeability of the material reduced from 1 to $S\tau$. Assuming the conductor to have unit permeability, β would be reduced from

$$2\pi\sqrt{\frac{f}{10^9\rho}} \text{ to } 2\pi\sqrt{\frac{S\tau f}{10^9\rho}}.$$

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For many purposes it is convenient to consider the ratio of the high-frequency resistance R_c of the coil to the high-frequency resistance R_f of the same wire when straight. In the present case this would necessitate a knowledge of the ratio R_f/R_o for a straight wire of square section. At low frequencies the resistance of a square wire approximates to that of a round one of equal cross-section, whereas at very high frequencies its resistance is inversely proportional to its periphery, and, neglecting the fact that the current density is slightly greater near the edges than near the middle of the faces, approximates to that of a round wire of the same periphery. For intermediate cases it will lie somewhere between these two limiting values. Now the area of a circle inscribed in a square has an area $\pi/4$ of that of the square and also a periphery $\pi/4$ of that of the square. Hence a round wire equal in diameter to the side of a square wire has $\pi/4$ times its resistance both at very low and at very high frequencies. It may be assumed therefore as an approximation that this ratio is constant at all frequencies. The resistance of linear conductors of square section has been investigated theoretically and experimentally by H. W. Edwards.* It will be found, however, that the inscribed circle method gives results in as good agreement with his observations as his own theoretically established formula. The biggest difference between the calculated and observed results is about 4 per cent. for values of $\tau\sqrt{f}$ ranging from 0 to 42.

The values of R_c/R_o and R_c/R_f have been calculated for a solenoid of square wire with $S\tau = 1{\cdot}0$, $0{\cdot}8$, $0{\cdot}5$ and $0{\cdot}25$ respectively, that is, for coils in which τ is 100, 80, 50 and 25 per cent. of the pitch of the turns. The results are given in Fig. 2. The curves are calculated by the above formulæ but the points marked are experimental results obtained by Esau who measured the high-frequency resistance of single-layer coils of square section. For the sake of comparison the curves have also been drawn for the values of $\tau\sqrt{f}$ and of $S\tau$ which were employed by Esau. It will be seen that the agreement is very good except for the lowest values of $S\tau$. Since the calculation is based on the assumption that $S\tau$ is not much less than unity, the accuracy with which the observed points lie on the curve when $S\tau = 0{\cdot}375$ is somewhat surprising, more especially in view of the enormous discrepancies when $S\tau = 0{\cdot}161$. It must

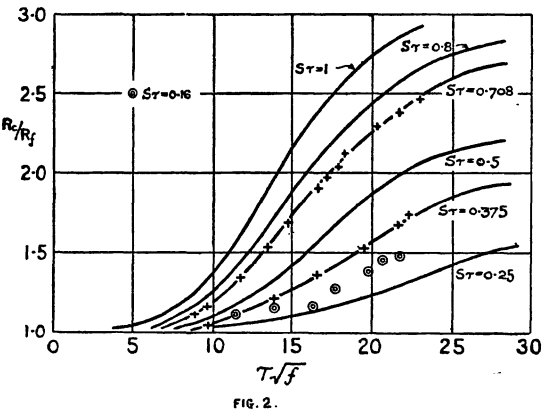

FIG. 2.

* *Electrician*, Vol. 68, p. 728, 1912; and *Physical Review*, Vol. 33, p. 184, 1911.

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be remembered that it has been assumed that the coils are long and that the diameter is large compared with the pitch.

Solenoid wound with Round Wire.—If the coil is wound with round wire the problem is more difficult. The only writers who appear to have attacked the problem rigidly are Picciati and Sommerfeld. Others have considered the problem, but have assumed, either that the wire is square, or that the current distribution in the round wire is similar to that in the square wire. Cohen assumed that the results obtained by him for square wire could be applied to round wire. His formula is only applicable to very closely wound coils,

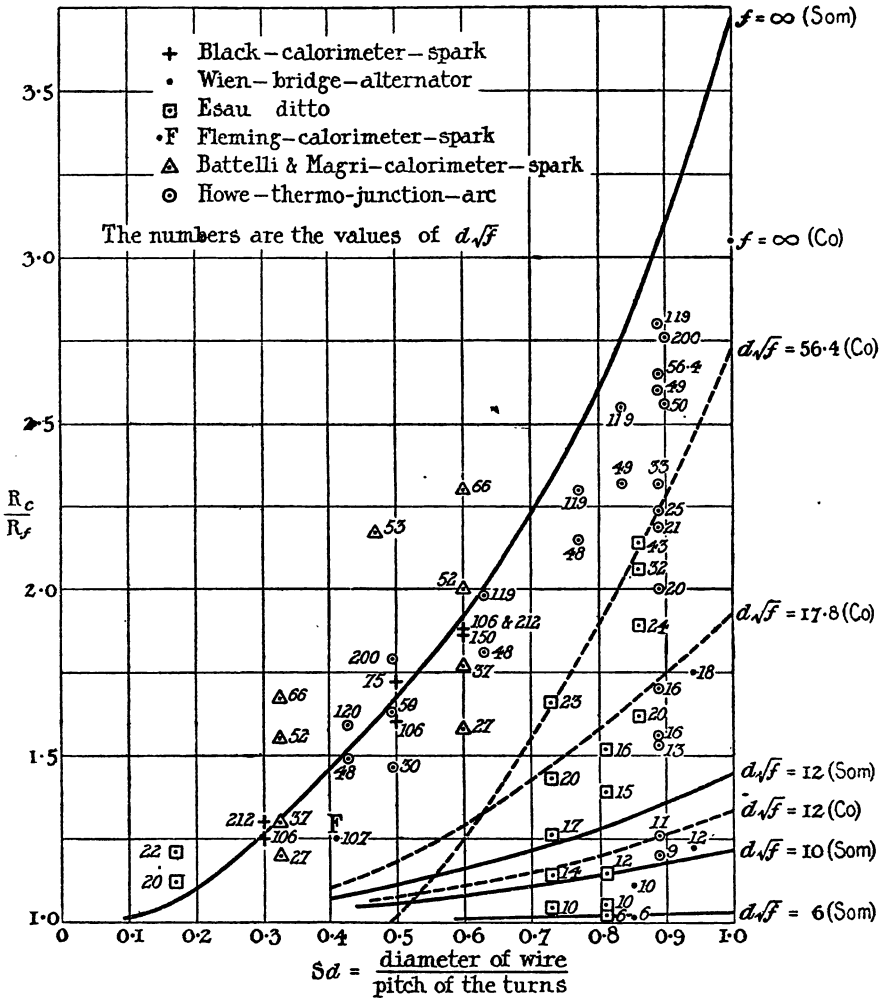

FIG. 3.

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and if applied to coils in which $Sd = 0{\cdot}5$, that is, in which the space between the wires is equal to the diameter of the wire, it may lead to coil resistances less than that of the wire when straight. As an example, the dotted curve in Fig. 3 is calculated by Cohen's formula for $d\sqrt{f} = 56{\cdot}4$. At low frequencies, however, Cohen's formula gives good results, even for coils which are not closely wound, as can be seen from the lower dotted curves in Fig. 3, for $d\sqrt{f} = 17{\cdot}8$ and $12{\cdot}0$ respectively.

For low frequencies M. Wien obtained the formula

$$R_c/R_o = 1 + 0{\cdot}272\,\pi^2\omega^2\sigma^2r^4\,(2\pi rS)^2$$

which, for copper, may be written

$$R_c/R_o = 1 + 23\,.\,10^{-6}\,(d\sqrt{f})^4\,.\,(Sd)^2$$

This is somewhat similar to the formula for low frequencies obtained by Sommerfeld, viz.

$$\frac{R_c}{R_o} = 1 + 0{\cdot}25\,\pi^2\omega^2\sigma^2r^4\,\left\{\frac{1}{3} + (2\pi rS)^2 + \frac{(2\pi rS)^4}{216} + \ldots\right\}$$

which, for copper, may be written

$$\frac{R_c}{R_o} = 1 + 2{\cdot}12 \times 10^{-6}\,(d\sqrt{f})^4\left\{\frac{1}{3} + \pi^2(Sd)^2 + \frac{\pi^4}{216}\,(Sd)^4 + \ldots\right\}$$

If Sd is not much less than unity, the second term is much bigger than any other, and we have approximately

$$R_c/R_o = 1 + 22{\cdot}7 \times 10^{-6}\,(d\sqrt{f})^4\,(Sd)^2$$

which is practically the same as Wien's formula. As mentioned in connection with parallel strips the accurate formula for closely-coiled square wire, viz. $R_c/R_o = \beta\tau/\gamma$, can be modified for small values of $\beta\tau$ by expanding the trigonometrical and hyperbolic functions and neglecting the higher powers of $\beta\tau$; in this way one obtains

$$\frac{R_c}{R_o} = 1 + \frac{2}{3}\cdot\frac{(2\beta\tau)^4}{5\,!}$$

$$= 1 + 47{\cdot}5 \times 10^{-6}\,(\tau\sqrt{f})^4 \text{ for copper.}$$

We have also shown that, if not closely wound, the effect is similar to that of reducing the permeability from 1 to $S\tau$, which would reduce β^4 in the ratio of 1 to $(S\tau)^2$, and give the formula

$$R_c/R_o = 1 + 47{\cdot}5 \times 10^{-6}\,(\tau\sqrt{f})^4\,.\,(S\tau)^2.$$

If this formula is assumed to hold approximately for round wires of equal cross-section, we have

$$\tau = 0{\cdot}886d;\ (\tau\sqrt{f})^4 = 0{\cdot}617\,(d\sqrt{f})^4;\ (S\tau)^2 = 0{\cdot}785\,(Sd)^2$$

and

$$R_c/R_o = 1 + 23 \times 10^{-6}(d\sqrt{f})^4(Sd)^2$$

in exact agreement with Wien and Sommerfeld. This formula is only applicable to low frequencies ($d\sqrt{f}$ less than 10).

At very high frequencies the replacement of closely-wound round wire by square wire of equal section also leads to results almost identical with those obtained by Sommerfeld. It should be mentioned that Sommerfeld only succeeded in solving the problem for the case of the turns in actual contact,

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i.e. for $Sd = 1$; for values of Sd less than unity, he used the experimental results of T. P. Black. We are therefore entirely dependent on experimental observations except for certain special cases. The results obtained by various experimenters have been plotted in Fig. 3; beside each point is given the value of $d\sqrt{f}$. The results are very discordant, but it must be remembered that the measurements have been made by different methods and with different sources of alternating currents; some with damped and some with undamped oscillations. The curves shown have been calculated by the various formulæ to which reference has been made. None of these formulæ take into account the effect of the diameter of the coil, which may be an important factor for small values of Sd; the formulæ assume the coils to be very long in comparison with their diameters, and they would obviously be very inaccurate if applied to narrow coils of large diameter (see section on "Short Coils").

EXPERIMENTAL.

A number of measurements of the high-frequency resistance of coils have been made at the Imperial College of Science and Technology during the last three or four years. The temperature rise of the coil was determined by means of a thermo-junction of very fine wires soldered to a point of the coil near its centre; these wires could be disconnected from the galvanometer circuit except when a reading was to be made. If I_o is the direct current required to give the same temperature rise as the alternating current I_c, then $I_o^2 R_o = I_c^2 R_c$.

The results obtained by this method are shown in Figs. 4 and 5. In Fig. 4 the coil consisted of 92 turns of 0·264 cm. wire, the total length of the coil was 26·9 cm. and its external diameter 2·86 cm. The ratio of the diameter of the wire to the pitch of the turns $= Sd = 3{\cdot}42 \times 0{\cdot}264 = 0{\cdot}9$. A fair curve has been drawn through the observed points. A square wire of equal cross-section would have a side $\tau = 0{\cdot}234$, therefore $S\tau = 0{\cdot}79$, and $\sqrt{S\tau} = 0{\cdot}89$.

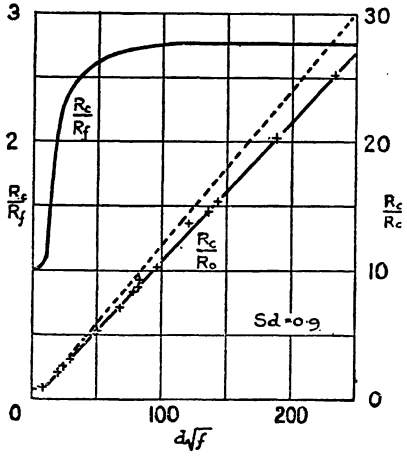

FIG. 4.

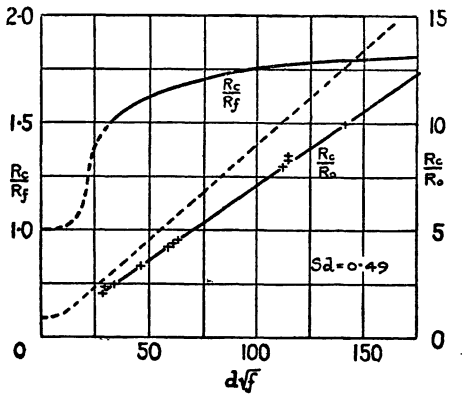

FIG. 5.

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Applying the formula for a coil wound with square wire, we have $\frac{R_c}{R_o} = \frac{\beta\tau}{\gamma}$, where $\beta = 0{\cdot}152\sqrt{f} \times \sqrt{S\tau}$, $\therefore\ \beta\tau = 0{\cdot}0316\sqrt{f}$. The corresponding values of R_c/R_o can be read off the curve in Fig. 1. These calculated values for the equivalent square wire are shown by the dotted curve in Fig. 4; they are about 11 per cent. greater than the measured values of R_c/R_o.

In Fig. 5 the coil consisted of 62 turns of wire 0·163 cm. diameter with a total length of 20·4 cm. and a pitch of 0·33 cm. A square wire of equal cross-section would have a side $\tau = 0{\cdot}144$ cm., $S\tau = 0{\cdot}436$, and $\sqrt{S\tau} = 0{\cdot}66$. Therefore $\frac{R_c}{R_o} = \frac{\beta\tau}{\gamma}$ where $\beta = 0{\cdot}152\sqrt{f} \times \sqrt{S\tau}$, $\therefore\ \beta\tau = 0{\cdot}1044\sqrt{f}$. The dotted curve shows the values of R_c/R_o calculated in this way. They are 26 per cent. higher than the measured values.

Exigencies of space sometimes compel the designer of radio apparatus to employ coils with more than a single layer of wire. The inductance increases as the square of the number of turns in a given length, whereas the resistance to steady currents is directly proportional to the turns. At high frequencies, however, the resistance may be greatly increased by the addition of a second or third layer.

Consider a long solenoid wound with three lengths of square wire. Numbering the layers from the outside, the magnetic field in the first annular space is due only to the current in the first layer, that in the second annular space is due to the currents in the two outer layers, and that inside the solenoid to the total current. These fields are therefore in the ratio of 1 : 2 : 3. If the frequency is very high the currents will be such as to prevent the penetration of these magnetic fields into the wires. The current I will be confined to the inner skin of the outer layer, the lost energy being transmitted radially into the wire from the annular gap. The flux will be prevented from penetrating very deeply into the second layer by a current I in the reverse direction in its outer skin, and a current 2 I—the field being twice as strong—in the forward direction in its inner skin. Similarly in the inner layer the penetration of flux is prevented by currents of $-2\ I$ and $+3\ I$ in the outer and inner skins respectively. The resultant current is of course the same in every layer, viz. I. Since the power lost is proportional to the square of the current the effective resistances are as tabulated below.

Hence if the size of wire and the frequency are such that the skin effect is very pronounced, the effective resistance increases much more rapidly than the inductance as the number of layers is increased. When, however, the penetration into the wires is considerable, the calculation of the effective resistance is much more complicated.

This problem was worked out in an appendix where it was shown that the power dissipated in any layer per axial centimetre is

$$P = i_2^2 \beta\rho F(\beta\tau,\ k)$$

where i_2 is the imaginary line current supplied at the outer end of the fictitious transmission line, ρ the specific resistance, τ the radial depth of each layer,

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and $F(\beta\tau, k)$ a complicated function, values of which were tabulated in the appendix.

If I be the actual resultant current in the coil per axial centimetre, the value of i_2 for the n^{th} layer is $(n-1)I$ and

$$P = (n-1)^2 I^2 \beta\rho F(\beta\tau, k)$$

whereas with an equal direct current $P = I^2\rho/\tau$. Hence for the n^{th} layer

$$R_c/R_o = (n-1)^2 \beta\tau F(\beta\tau, k).$$

The values of R_c/R_o have been calculated by this formula for the second, third, and fourth layers, and the results are tabulated both for the individual layers and for the complete coils.

MULTI-LAYER COILS.

Number of Layers.	Current in Outer and Inner Skin.	Relative Power dissipated in each Layer.	Relative Power dissipated in all Layers.	$\frac{R_c}{R_o}$	Relative Inductance.
1	$\left\{\begin{matrix}0\\ I\end{matrix}\right.$	$\left\{\begin{matrix}0\\ 1\end{matrix}\right\}$ 1	1	$\beta\tau$	1
2	$\left\{\begin{matrix}-I\\ 2I\end{matrix}\right.$	$\left\{\begin{matrix}1\\ 4\end{matrix}\right\}$ 5	6	$3\ \beta\tau$	4
3	$\left\{\begin{matrix}-2I\\ 3I\end{matrix}\right.$	$\left\{\begin{matrix}4\\ 9\end{matrix}\right\}$ 13	19	$6\frac{1}{3}\ \beta\tau$	9
4	$\left\{\begin{matrix}-3I\\ 4I\end{matrix}\right.$	$\left\{\begin{matrix}9\\ 16\end{matrix}\right\}$ 25	44	$11\ \beta\tau$	16
5	$\left\{\begin{matrix}-4I\\ 5I\end{matrix}\right.$	$\left\{\begin{matrix}16\\ 25\end{matrix}\right\}$ 41	85	$17\ \beta\tau$	25

The curves in Fig. 6 give the values of R_c/R_o for coils with various numbers of layers. For high values of $\beta\tau$ the curves approximate to the dotted lines in accordance with the values given in the Table above.

These curves refer to long coils closely wound with square or rectangular wire, and corrections must be applied for the spaces between adjacent turns, and for the coil not being very long compared with its diameter. The results are not affected, however, by the space between adjacent layers. As we have shown in the case of single-layer coils, the effect of spacing between adjacent turns, if not excessive, can be allowed for by taking the value of R_c/R_o for $\beta\tau\sqrt{(S\tau)}$ instead of for $\beta\tau$, where S is the number of turns per centimetre and τ is the side of the square. With round wire an approximate result can be obtained by assuming it to be replaced by square wire of equal sectional area.

THE USE OF MULTIPLY STRANDED INSULATED WIRE.

The author referred to a previous paper* on this subject in which

* *Proceedings of the Royal Society*, A, Vol. 93, p. 468, 1917.

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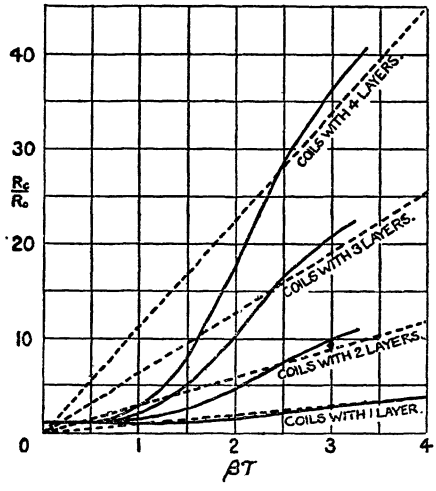

FIG 6.

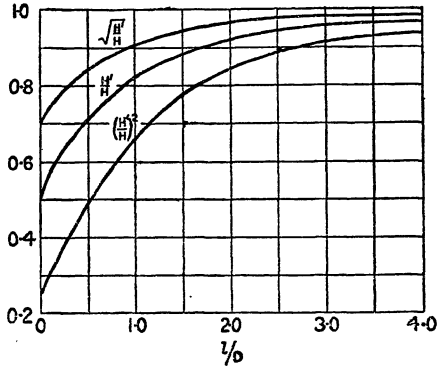

FIG. 7.

formulæ were given for the calculation of the high-frequency resistance of multiply stranded insulated wire. An application of the formula to a coil of given dimensions gave results in good agreement with the measured values.

Another interesting fact which was shown in the paper referred to was that the minimum high-frequency resistance was not obtained by putting as many individual wires as possible into the available space, but that there is an optimum space-factor beyond which the addition of more wires increases the resistance.

In many cases the fine wires are not distributed uniformly throughout the cross-section of the conductor but are confined to the outer surface, the wires being plaited around a non-conducting core. The formulæ can easily be modified and applied to such cases.

The use of stranded wires in coils of more than one layer has not yet been considered but presents no difficulties. Numbering the layers from the outside the average values of H^2 in the first three layers are in the ratio of 1 : 7 : 19, and the eddy losses are proportional to these values. Hence in a two-layer coil the total eddy loss is eight times that in a single-layer coil, whilst in a three-layer coil it is twenty-seven times that in a single-layer coil. The ratios of the eddy loss to the steady current loss are therefore as 1 : 4 : 9 and the formulæ become :—

In a single-layer coil $R_c = R_o\{1 + 35{\cdot}6 \times 10^{-6}\, nf^2d^4a(S\tau)^2\}$

In a two-layer coil $R_c = R_o\{1 + 4 \times 35{\cdot}6 \times 10^{-6}\, nf^2d^4a(S\tau)^2\}$

In a three-layer coil $R_c = R_o\{1 + 9 \times 35{\cdot}6 \times 10^{-6}\, nf^2d^4a(S\tau)^2\}$.

These formulæ assume infinitely long solenoids; if the coil is short the value must be corrected as explained under "Short Coils." The formulæ will not be accurate for values of $S\tau$ less than about 0·5.

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SHORT COILS.

The calculated formulæ for the high-frequency resistance of coils are all based on the assumption that the coils are very long in comparison with the diameter. In a short coil the density of the magnetic flux at the inner side of the wire is less than in a long coil with the same number of ampere-turns per centimetre. The effect of spacing between adjacent turns was shown to be equivalent to a reduction of the permeability in the expression for β for a closely-wound coil. The reduction of flux density due to the coil not having infinite length can be treated in the same way. The value of R_c/R_f for a short coil can be read off the curve for a closely-wound infinitely long coil if instead of $\beta\tau$ one takes the value

$$\beta\tau\sqrt{S\tau}\,.\,\sqrt{H'/H}.$$

where H is the flux density in a long solenoid and H' that in the short coil, the values being determined at the inner side of the wire. The correcting factor $\sqrt{S\tau}$ has already been discussed.

The author has calculated the ratio H'/H for various values of l/D and the results are shown in Fig. 7.

The effect on R_c/R_f of multiplying $\beta\tau$ by $\sqrt{H'/H}$ may be small or great depending on the value of $\beta\tau$ as can be seen in Fig. 1.

In the case of multiply-stranded insulated wire the eddy-current loss in the individual wires is proportional to H^2. In this case the term in the expression for R_c/R_o which depends on the eddy-current loss, that is, the second term, must be multiplied by $(H'/H)^2$. An example of this correction occurred when considering the experimental result obtained by Lindemann.

DISCUSSION.

Professor C. L. FORTESCUE said that although the transmission line idea might be helpful to those who were very familiar with it, it was not essential in considering high-frequency resistance. He maintained that there were many cases in which the use of insulated stranded wire was thoroughly justified; he gave a numerical example in support of this view. He also pointed out that at high frequencies the self-capacity of a coil caused the current in it to differ from that read on the ammeter in series with the coil.

Mr. P. R. COURSEY also referred to this point and drew attention to the correction factor obtained by assuming the self-capacity C_o to be connected between the terminals, in which case it is easily seen that

$$\frac{\text{apparent current}}{\text{real current}} = 1 - \omega^2 C_o L_o.$$

Mr. Coursey also gave some measured values of R_c/R_o, some of which were considerably greater than the calculated values.

Mr. H. W. TAYLOR pointed out that the losses in the inner layers of a multilayer coil could be determined by adding the losses due to their own magnetic fields to those due to the field produced by the other layers. These components can be determined by relatively simple hyperbolic formulæ. The results so obtained agree with those given in the paper. Mr. Taylor thought that the term 0·25 in the formula for the value of R_f/R_o for a straight round wire was due to an error in the approximation made.

Mr. FRANK MURPHY referred to the losses which may occur in the dielectric used to insulate the wires.

Mr. R. C. CLINKER pointed out the possibility of non-uniform heating of the coil under experiment due to the effect of the end turns.

Dr. ECCLES drew attention to the fact that the author had followed Sommerfeld and others in plotting curves which were supposed to apply when the frequency was infinitely great. Long before this was reached, however, the current in the coil would have nodes and antinodes owing to the capacity effects.

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Direction and Position Finding.*

By Captain H. J. ROUND.

THE major portion of this paper is confined to a sketch of the war development of direction and position finding as far as it was known to the author. An elementary account of the general ideas involved in wireless direction finding is first given, dealing with the phase difference between the currents induced in two receiving aerials spaced a fraction of a wavelength apart, and of its resulting applications in frame or loop aerial reception. A number of polar diagrams are given for various aerial arrangements.

HISTORICAL SKETCH OF DEVELOPMENT.

Fitzgerald, before Hertz, suggested frames for radiating, and probably with his insight into things, noted possible directional properties. Hertz undoubtedly recognised directional properties in his receiving loop. About 1899, 1900, and 1901, S. G. Brown and others suggested the use of spaced aerials for the purpose of obtaining non-circular radiation. The frame aerial was probably first suggested by Lee de Forest. In 1906 Braun combined aerials to give heart-shaped polar diagrams of radiation. Marconi arranged the first direction-finding system which utilised the position given by signals when at their maximum strength.

In 1905 a number of experiments were carried out by the author using multi-turn receiving frames. Signals were received up to three miles. Artom suggested and used a directional method, but the indefiniteness of the original description prevented any clear conception of his ideas. Bellini and Tosi revived the subject, and in 1912 Major Prince modified the Bellini aerial to complete frames. The development of simplified receiving circuits using triode valves for both high and low frequency magnification suggested the revival of the radiogoniometer almost immediately after war broke out.

Early War Trials.—In the preliminary experiments (September, 1914) a number of errors were encountered, due apparently to two causes:

(1) Coupling between the two aerial systems not due to the search coil. This gave maximum errors in the plane of either aerial.

(2) Incorrect tuning and consequent mis-phasing of the two aerial systems. This gave maximum errors in the plane of 45° between the two aerials.

Another series of errors appeared afterwards due to badly constructed aerial tuning condensers and to dielectric losses in these condensers. Even with air condensers losses due to imperfect contact with the vanes also gave trouble.

Aerial Systems.—The first aerial systems were small diamond-shaped frames supported by 70-foot wooden masts. A little later on four masts were used to support square frame aerials. This seems to be the best form for all-round accuracy. Still later, on account of the cost of masts, the

* Abstract of paper read before the Institution of Electrical Engineers (Wireless Section) on January 14th, 1920.

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diamond-shaped frames were reverted to, supported by one high central mast and four small corner masts.

Radiogoniometers.—During the war practically no changes were made in the dimensions of the radiogoniometer coils designed by Bellini, except in the number of turns on the windings.

Two dimensions of coils were used for different circumstances :—

(*a*) "Tight coupled," fixed coil $5\frac{7}{8}$ inches high × $5\frac{1}{4}$ inches wide, moving search coil $4\frac{1}{2}$ inches high × 4 inches wide.

(*b*) "Loose coupled," fixed coil same as (*a*), moving search coil $3\frac{1}{8}$ inches diameter.

Actually both types were tightly coupled at the maximum.

It was found that if the aerials were tuned to, say, 800 metres, and carefully balanced or phased, then by returning the intermediate and final circuits, but without altering the aerial tuning, signals could be received with only slight falling off in strength between 600 and 1,000 metres. This was due to the above-mentioned tight coupling of the radiogoniometer.

Apart from the above-mentioned errors, others were not at first serious.

First Valves and Circuits.—In the first year of work soft valves were used. No hard valve has been constructed which can compare with these "C" type tubes as high-frequency magnifiers. A comparison of characteristics indicates that the "C" valve is equal in magnifying power either to sixteen hard "French" tubes in parallel, or to three in cascade. With the "C" valve the average high-frequency magnification, using reaction, was about 150.

Everything seems to suggest that long ageing is necessary to produce a steady valve unless success is obtainable with a gas such as helium or neon. Curiously enough a spectrum analysis of an old tube never showed anything but hydrogen, but with hydrogen the author was never able to make a tube that was any good.

Another Source of Error.—Quite early in 1915 another error appeared which was nicknamed "Vertical." It was noticed that the two positions of zero reception were seldom opposite to one another. This was traced to a small "vertical aerial" receptive power of the loop, chiefly due to the difference in the capacity of the grid of the valve to earth, and of its battery to earth. It was corrected at first by adding a small condenser from the grid of the valve to earth. The capacity of this condenser should equal the capacity of the batteries to earth. With the use of hard valves, these "vertical" troubles increased, and they increased still more when aperiodic aerials were used.

Night Errors.—Probably it has occurred to some that the extraordinary variation of signals at night, so different from the constancy during the day, might be accompanied by variations in apparent direction. Captain Tremellen working at a D.F. station at Abbeville (France) noticed this effect first with KAV. A copy of his original curve taken of KAV's apparent movements during the sunset period is shown in Fig. 1. This curve is typical of a sunset movement. This night variation remained throughout the war a serious defect in the direction finding work. Captain Tremellen and

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Lieutenant Adcock in France and particularly Lieutenant Eckersley in Egypt succeeded in obtaining valuable information about these variations. An interesting point regarding these effects was discovered later. The Germans had two "radiophare" stations for enabling their fleet and submarines to determine their position without having to transmit. These radiophares in effect consisted of a rotating frame continually sending during rotation. A signal was sent to give the zero of time, and any ship noting the time interval between this zero and the zero of signals could determine its angular position from the station. The fact that a frame transmits vertically as well as horizontally, and that at different points in its rotation the vertical radiation is polarised in a different direction, should lead one to expect curious results at night. Notwithstanding the difficulty of taking quick bearings, Captain Tremellen was able to note a large variation in the apparent direction of these stations at night as the frame rotated. Unfortunately these stations have now stopped work or a complete investigation of this effect would have been undertaken.

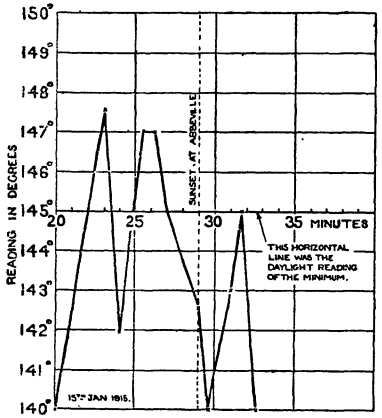

FIG. 1.

(To be concluded.)

The Transmission of Electromagnetic Waves about the Earth.*

By J. ERSKINE-MURRAY, D.Sc., F.R.S.E.

This paper gave a brief *résumé* of the known facts about the transmission of electrical waves round the earth.

An account was first given of the classical experiments made by Duddell and Taylor at Howth, after which the lecturer showed diagrams illustrating the form in which the waves are bent back by reason of the energy wastage by the currents induced in the earth. From this it follows that the effective waves arriving at a receiving station must have reached that station from some part in the upper atmosphere, as the direction of maximum energy slopes down towards the receiving aerial. This energy must therefore have left the transmitter in an upward sloping direction, and the idea is thus introduced of the reflection or refraction of the waves somewhere in the upper atmosphere, in order to account for the waves being bent down again towards the receiver. The first suggestion of such a conducting and reflecting

* Abstract of paper read before the Wireless Society of London, December 19th, 1919.

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surface in the upper atmosphere was due to G. T. Fitzgerald in 1893. Heaviside also brought forward the same idea at a later date.

The variation in the received signal strength by day and by night was first noticed by Marconi in 1902 in some tests made in a voyage across the Atlantic. The classical experiments of Dr. Austin were also referred to, and it was pointed out that Dr. G. N. Watson has recently shown that a layer of ionised air having a specific resistance of $6{\cdot}95 \times 10^5$ ohms and at a height of about 100 km. would just give the same results as Austin's formula.

The major portion of Dr. Erskine-Murray's paper was devoted to an account of some extensive experimental work carried out by Dr. de Groot in the Dutch East Indies.

The 5-kw. station at Sabang, which has a normal range of only 150 miles, can at night be heard at a distance of about 3,000 kms. and again at about 6,000 kms. at Osaka, in Japan. At the intermediate points this station is not heard. A very regular reflection of the waves by the ionised layer is thus indicated. In the case of stations nearer to the transmitter the waves would require to be reflected by the ionised layer at a much greater angle than for the stations further away. When the angle of incidence of the rays at the reflecting layer is large a considerable proportion of wave energy passes through, but as the angle is reduced a point is reached at which practically all the energy is reflected. This angle is such that the reflected waves reach the earth's surface again at about 3,000 kms. from the transmitter.

The most interesting part of de Groot's work deals with daylight transmission, and in particular transmission between two stations about 1,000 kms. apart (Sitoebonda and Koepang). Curves of signal strength measurements were taken over prolonged periods by de Groot and some sample curves were shown in the paper.

In these curves the sunrise and sunset effects which figure so prominently in transmission in the Northern latitudes have practically disappeared and in their place there was found a large absorption somewhere near mid-day. De Groot found that there were certain definite relations between the sun's position and these maxima of absorption, and that whenever the sun was vertical over either one or other of four great circles of the earth, the absorption was greatest.

The chief conclusions drawn from these tests seemed to indicate that the ionised layers are bent down to be as nearly as possible always perpendicular to the sun's rays, hence near mid-day there is a fairly regular reflection and refraction of the waves between the two stations.

In the morning or evening the ionised layers are apparently bent down to an angle somewhere near 45° to the earth's surface and hence the waves which normally leave the transmitter at somewhere about that angle in order to reach the receiver only graze along the surface of these layers and are reflected off into space and their energy is lost. For a wave to reach the receiver it must leave the transmitter in an almost vertical direction, in order to strike the ionised layers at suitable angles for reflection and refraction down to the receiving station. But the energy which normally leaves the transmitting aerial in a nearly vertical direction is very small as compared

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with that leaving horizontally, so that at this time in the day very little energy will reach the receiving station. Later on as the layers become more level the conditions become more regular, but still later when they are inclined again on the evening side of mid-day conditions are similar to those in the morning and a minimum of received energy is again found.

Some rather complex diagrams were given by Dr. Erskine-Murray illustrating the various planes and reflecting layers concerned in this transmission, but the general result of all the experiments cited seemed to support the views expressed above.

In the discussion, the question was raised as to whether freak communications in and around Europe took place more frequently in the North-South or East-West direction, but it was pointed out that although such communications apparently occurred most frequently in a North-South direction this is in all probability due to the larger number of stations lying in that general direction which are heard on such occasions.

It was also stated that the receiver used by de Groot was a carefully calibrated crystal detector and that the signal strength measurements were made by the shunted telephone method. It was suggested that some of the variations in the apparent direction of a station as determined by direction-finding apparatus may be due to these variations which take place in the planes of the ionised layers.

A Comparative Method of Testing Thermionic Valves for Passing no Reverse Current at High Voltages.*

By N. W. MACLACHLAN, D.Sc., M.I.E.E.

In using two three-electrode thermionic valves for determination of the maximum or peak voltage of an alternating current supply, and in the determination of the decrement of a circuit in which the damping is very high, it is essential that the valve should pass no reverse current. The author in this paper describes some experimental tests carried out with a view to ascertaining the magnitude of the reverse current passed by such valve rectifiers.

The simplest method of carrying out such tests is to use a high tension direct current source. This may be obtained by rectification and storage in condensers as recently described by Professor Fortescue.†

As an alternative method two rectifying valves may be connected in series in opposition to one another and fed from a high tension A.C. supply. As a convenient method of indicating the reverse current passed by the valves a condenser may be joined in the circuit with them and a low reading voltmeter connected across its terminals. Both the valves and their filament batteries must be very well insulated. If neither valve passes any reverse current there will obviously be no reading on the voltmeter connected across the condenser, but if either of the valves passes some current a reading will

* Abstract of paper read before the Physical Society of London, December 12th, 1919.

† *Proceedings of the Physical Society of London*, 31, pp. 319-337, August, 1919 (RADIO REVIEW, Abstract No. 12).

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be obtained. Tests are mentioned in the paper of two valves connected in this way supplied from 18,000 volts, when no reverse current was indicated by an E.S. voltmeter which could indicate down to five volts.

The second section of the paper deals with the measurement of the decrement of highly damped oscillations with the aid of a rectifying valve. The method described is indicated in Fig. 1.

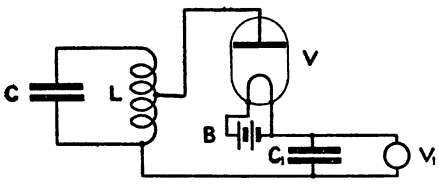

FIG. 1.

The valve must be known to pass no reverse current—which can be ascertained by testing it in the manner described above. The reading of the voltmeter V_1 is proportional to the peak voltage of the first semi-oscillation in the circuit CL, and by reversing the valve the peak voltage of the next semi-oscillation is obtained.

The third section of the paper deals with the measurement of decrement in a magneto using a similar method to the above.

The Physical Society of London Exhibition.

The tenth annual exhibition of the Physical and Optical Societies was held at the Imperial College of Science, South Kensington, on January 7th and 8th.

Amongst the usual exhibits of physical apparatus there were several of wireless interest, amongst which may be mentioned:—*The Edison Swan Electric Co., Ltd.*, who exhibited: A series of service valves for wireless reception and transmission; a series of Marconi valves made by the Edison Swan Co.; a series of original types of receiving valves for amateur and commercial use; and various special types of rectifying and transmitting valves designed by Mr. Scott-Taggart.

Marconi's Wireless Telegraph Co., Ltd., showed some instruments suitable for measuring high-frequency currents; their new Marine pattern of Radio direction-finding apparatus; and their seven-valve amplifier, connected to a frame aerial receiver.

The Marconi-Osram Valve Co. exhibited a large number of different types of receiving, transmitting and rectifying valves manufactured by them, including some recent designs for commercial use.

The Dubilier Condenser Co., Ltd., showed various patterns of high-tension and receiving condensers manufactured for wireless use.

Messrs. H. W. Sullivan demonstrated a special oscillating valve set for generating alternating currents of any desired frequency for use in electrical measurements, also the production of beats between two such oscillators; and a number of different patterns of variable condensers for wireless receiving and other uses.

Amongst the exhibits of captured German apparatus were types of Telefunken transmitters and receivers, and also a valve amplifier.

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Review of Radio Literature.

1. Abstracts of Articles.

180. THE WAVELENGTHS RADIATED FROM OSCILLATING VALVE CIRCUITS. S. R. Humby and B. F. J. Schonland. (*Electrician*, 83, pp. 443—444, October, 1919.)

When two oscillation circuits are coupled together and oscillations are set up in them there are usually two oscillation frequencies established. This paper investigates this case when the oscillations are maintained by a valve, the two coupled circuits being included in the grid and plate circuits respectively of the valve.

It is shown that when the coupling is in the normal direction for the maintenance of oscillations, there is only one wavelength radiated (with its harmonics) of length equal to the longer of the two "coupling" waves. With the reaction coupling reversed the wavelength radiated (when the valve oscillates) is the shorter one only of the two coupling waves. It is stated that the authors have been led to the conclusion that the phase difference between the oscillatory currents in the grid and plate circuits can be either 0° or 180°, but cannot have values differing sensibly from these.

A mechanical analogy of the valve operation is given, and also some further measurements on the wavelengths radiated when the aerial circuit is directly coupled to the plate circuit, by tappings from the plate-circuit inductance—referred to as the "anode tap" connection.

181. APPLICATIONS OF THE CATHODE RAY TUBE IN RADIO WORK. L. E. Whitmore and L. M. Hull. (*Physical Review*, 14, pp. 266—267, September, 1919. Abstract of paper read before American Physical Society.)

Two general types of cathode ray tube have been used for investigating the oscillations in radio frequency circuits at the Bureau of Standards, Washington, those having the usual plain cathode and those having a hot filament cathode. The former require exciting voltages of from 8,000 to 20,000 volts and are suitable for the investigation of oscillating current of the order of magnitude of one ampere. The high-tension voltage is obtained by double-valve rectifiers from an A.C. supply, using condensers and choke coils to smooth out the rectified wave. With the second type using a Wehnelt cathode, from 500 to 1,000 volts is required and the tube is suitable for the investigation of oscillating currents of the order of 0·05 amp. On account of the relatively low exciting voltage this type of tube is much more sensitive to electrostatic and electromagnetic deflections. These oscillographs are being used in an investigation of the harmonics in aerial circuits excited by vacuum tube generators.

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182. A SIMPLE DERIVATION OF THE FORMULÆ FOR THE RESONANCE CURVES OF A DAMPED VIBRATION AND SOME PROPERTIES THEREOF. Balth. van der Pol. (*Electrician*, 83, pp. 225—228, 251—252, September, 1919.)

The Bjerknes resonance curve formula is only strictly applicable under certain conditions of coupling and damping, and only over a limited range of frequency difference. The mathematical development of the formula is greatly simplified by introducing these limitations at an early stage, since approximations can then be made, which would not be permissible in a general treatment of the problem. By adopting this procedure the author gives a relatively simple derivation of the Bjerknes formula. He also derives the formula for the dynamometer method due to Mandelstam and Papalexi, in which the reading passes through zero at the resonant point. Attention is drawn to a number of interesting relationships between the two types of resonance curves and their similarity to resonance curves met with in other branches of science, *e.g.* in the motional resistance and reactance of a telephone diaphragm and in the variation of absorption with the frequency when light passes through an absorbing medium.

183. THE MEASUREMENT OF ALTERNATING WAVES WITH THE BRAUN TUBE. E. Lubke. (*Archiv. für Elektrotechnik*, 5, pp. 314—334; 6, pp. 161—164. *Jahrbuch der Drahtlosen Telegraphie*, 13, p. 102. *Electrician*, 83, pp. 270—273, September, 1919.)

The author deals with the application of the Braun Cathode ray oscillograph to the delineation of A.C. wave forms, not by the usual method in which the curves are traced out on the fluorescent screen, but by the use of the Joubert contact method. For this purpose the stream of cathode rays is employed to form the contact maker. The arrangement is thus available for much higher frequencies than when the customary mechanical contact is employed.

The beam of cathode rays is caused to rotate and trace out a cone-shaped figure under the influence of the magnetic field due to the oscillations whose wave form is to be investigated. At one point in its rotation the beam passes through a narrow slit and then between two small condenser plates—thus ionising the space between them. These condenser plates take the place of the usual contact maker, and the ionisation of the space between them completes the circuit of an electrostatic voltmeter at any desired point in the cycle of the oscillations. By moving the deflecting magnet round the axis of the Braun tube this point in the cycle may be varied at will.

Examples of curves taken with this method are given in the paper.

For very high frequencies the condenser plates "contact" are replaced by a second smaller tube containing a fluorescent screen, and constricted near the slit to enable the beam entering this second tube from the slit in the first

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tube to be deflected electrostatically by the potential to be measured at that instant in the cycle. The measurements are thus made from point to point through the cycle as before but by the deflection of the spot on the screen in the second tube instead of on the E.S. voltmeter.

With this apparatus the wave form of oscillations of frequencies up to $3 \times 10^6 \sim$ ($\lambda = 100$ metres) can be delineated using cathode rays excited by a 220-volt source. With higher voltages, and higher speed rays, still higher frequencies are possible.

184. AN IMPROVED METHOD FOR DETERMINING THE ELECTRICAL CHARACTERISTICS OF HIGH-FREQUENCY OSCILLATION CIRCUITS. N. P. Hinton. (*British Patent* 132022, September, 1918. Patent accepted, September 2nd, 1919.)

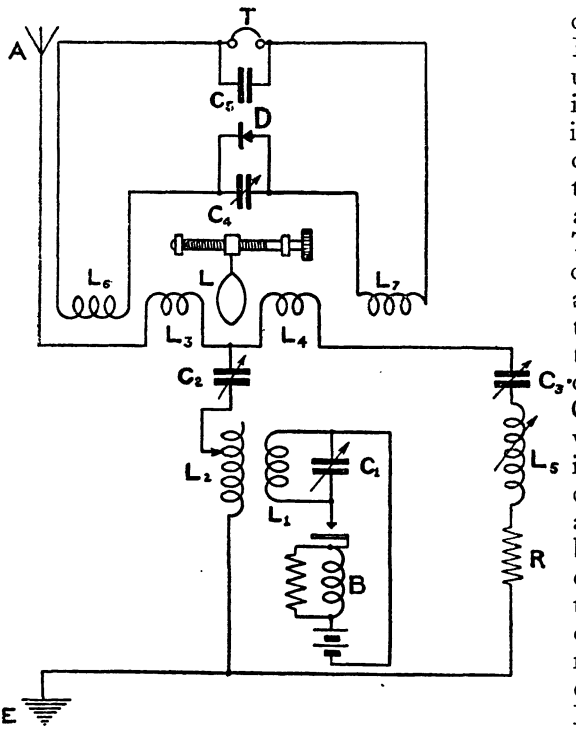

FIG. 1.

The arrangement described is indicated in Fig. 1. The buzzer B is used to excite oscillations in the circuit C_1 L_1 and is coupled to the tuned circuit C_2 L_2 and thence to the two circuits L_3 A E and L_4 C_3 L_5 R in parallel. The coils L_3 L_4 are coupled to L_6 L_7 which are joined in series with the detector D and the telephones T. To carry out a test the condenser C_1 is set to the required wavelength, the measuring circuit C_3 L_5 R is disconnected and the aerial circuit A E is tuned by adjusting the condenser C_2 and the inductance L_2. The standard circuit C_3 L_5 R is then reconnected, and the condenser C_3, the inductance L_5, and the resistance R are adjusted until no sound is heard in the telephones T. A switch is provided for interchanging the primary coils L_3 L_4 to eliminate any errors arising from inequalities in their windings. The mean of the two values obtained for the capacity C_3, the inductance L_5, and the resistance R gives the values of the corresponding characteristics of the aerial circuits which were to be measured.

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185. QUANTITATIVE EXPERIMENTS WITH COIL ANTENNAS IN RADIOTELEGRAPHY. L. W. Austin. (*Revue Générale de l'Électricité*, 6, pp. 551—552, October, 1919.)

See RADIO REVIEW, Abstract No. 3 for the original paper.

186. THE USE OF AMPLIFIERS FOR MEASURING SMALL DIFFERENCES OF POTENTIAL. A. Blondel. (*Revue Générale de l'Électricité*, 6, pp. 163—177, August, 1919.)

This paper deals with the use of amplifying valves for the measurement of small differences of static potential. Various arrangements are described and formulæ given for the calculation of their sensitiveness. The various methods dealt with are classified into :—

(1) Thermionic Balance Method.
(2) Static Bridge Method.
(3) Deflectional Bridge Method.
(4) Potentiometric Methods.

(1) The leading idea of the first group is the use of a differential galvanometer, one winding of which forms part of the plate circuit of the valve, while the circuit through the other includes only a resistance to balance the internal resistance of the valve, and so reduce the galvanometer deflection to zero. A small E.M.F. applied to the grid of the valve causes a deflection of the galvanometer. In a modification a valve may be included in each winding of the galvo to give increased sensitiveness.

(2) In the second type of arrangement the valve forms one arm of a Wheatstone bridge. Readings are obtained by rebalancing the bridge when the E.M.F. to be measured is applied to the grid of the valve. Alternatively two valves may be used in adjacent bridge arms, with their grids so connected that on the application of the E.M.F. to be measured the effective resistance of one valve is increased, while the other is reduced.

(3) The third method is essentially the same as the second except that the bridge is not rebalanced for each reading, but measurements are made by noting the deflection of the bridge galvanometer when the bridge is put out of balance by the application of the E.M.F. to be measured.

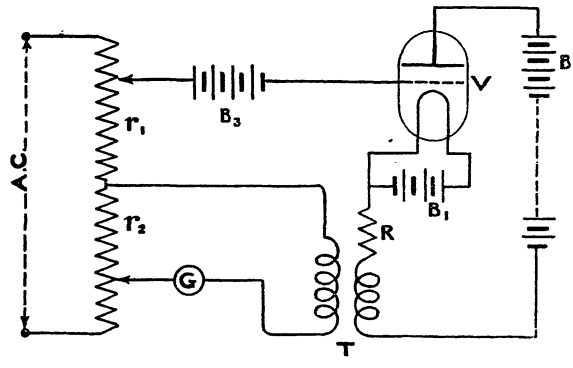

FIG. 2.

An initial amplification stage may be added to any of these methods, and results in increased sensitiveness.

(4) The fourth class of arrangement considered in the paper is an application of the

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known methods of measurement of the amplification ratio of a valve, by using a potentiometer to apply a voltage to the grid circuit and to balance out the resultant amplified voltage in the plate circuit. Two modifications of this are described to enable the amplification ratio to be measured with the valve under working conditions, viz., with the plate circuit closed and the normal current flowing. One of these with a transformer winding in the plate circuit is indicated in Fig. 2.

An appendix to the paper describes the measurement of the internal resistance of a valve by including the valve in one arm of a bridge, with the bridge battery to supply the plate circuit, and with a superposed A.C. source in the battery arm of the bridge.

187. ROTARY SPARK GAPS. Compagnie Générale de Radio-Télégraphie. (*French Patent* 494557, filed January 8th, 1919. Published September 12th, 1919.)

This patent relates to a rotary spark gap in which the spark is displaced on the electrodes and in the gap quicker than the peripheral speed of the moving parts, by causing it to follow the continuous movement of the teeth on the rotating member very obliquely in relation to the teeth on the fixed member. The object of the quick displacement of the spark is to reduce wear of the electrodes and to obtain an energetic and automatic quenching of the spark. It is stated to be applicable in the case of shock excitation.

188. SPARK GAPS. Alphonse Kowalski. (*French Patent* 495034, filed July 16th, 1917. Published September 26th, 1919.)

In a spark gap with two electrodes arranged one above the other, for high frequency sparks, the lower electrode is formed by a metal tube connected to a supply of gas under pressure, and is surrounded, with a space between, by an insulating tube which projects upwards to the lower extremity of the upper electrode. This tube is also connected with a supply of gas under pressure, but lower than the pressure of the gas connected to the electrode, so that the spark produced between the electrodes is guided towards the walls of the tube, without, however, touching them, and then towards the space between the insulating tube and lower part of the upper electrode.

189. IMPROVEMENTS RELATING TO RADIOTELEGRAPHIC TRANSMITTING SYSTEMS. A. Taylor. (*British Patent* 131561, April, 1919. Patent accepted, August 28th, 1919.)

In radiotelegraphic transmission systems in which signalling is effected by altering the inductance of the aerial circuits, arrangements are made so that this inductance is split up into a number of separate sections which are short-circuited independently. These short-circuiting contacts are all operated by a single solenoid switch actuated by the signalling key.*

190. ELIMINATING PARASITIC SIGNALS. L. Lévy. (*British Patent* 133306, October, 1918. Abridgment published, December 3rd, 1919.)

The receiver described is suitable for C.W. heterodyne reception and is

* See also RADIO REVIEW, Abstract No. 114.

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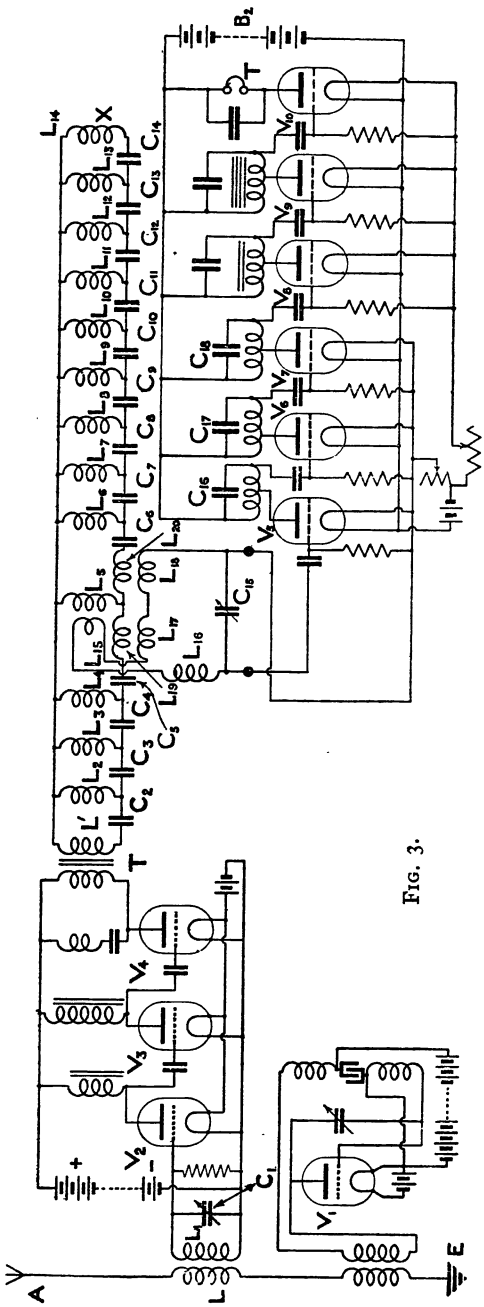

FIG. 3.

specially arranged for eliminating parasitic disturbances. The incoming oscillations from the aerial circuit ALE (Fig. 3), are heterodyned by the local oscillations set up by the oscillating valve V_1, which is arranged so that the beat frequency is supersonic—say about 10,000 ~. The resulting currents are amplified by valves V_2, V_3, V_4 (which form a cascade amplifier as indicated), and are then impressed through T upon the filter circuit TX, made up of condensers and inductances C_2L_2, C_3L_3, C_4L_4 . . . $C_{14}L_{14}$. The natural wavelength of this circuit is adjusted to resonate with the chosen supersonic beat frequency. Stationary waves are set up in this circuit by reflections at the terminal inductances L',L_{14} which have twice the inductance of the others. The circuit $L_{15}L_{16}L_{17}L_{18}C_{15}$ is tuned to the beat frequency, and is coupled to one of the filter coils—say L_5—and to two additional coupling coils (L_{19}, L_{20}) joined in series between adjacent filter circuit condensers. By connecting the "potential" coupling $L_{15}L_5$ in opposition to the "current" coupling coils L_{17}, L_{18} it is claimed that the effect of an atmospheric on circuit $L_{15}L_{16}C_{15}$ can be eliminated, since an atmospheric will set up only one or two oscillations which will travel through the filter as a progressive wave, instead of setting up a stationary wave. The purified supersonic current is further amplified by the valves V_5—V_{10}. The circuits of V_5, V_6 and V_7 are tuned to a

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frequency near to the supersonic beat frequency,—the capacities of C_{16}, C_{17}, C_{18} being greater than the resonance value and increasing in this order. An audible beat frequency is thus obtained, which is amplified by V_8, V_9, V_{10} for detection by the telephones T. In a modification the filter may be distributed along the aerial circuit.

191. SYSTEM OF ELECTRICAL TRANSMISSION SPECIALLY APPLICABLE TO WIRELESS TELEGRAPHY AND TELEPHONY. L. Lévy. (*French Patent* 493660, August, 1917. Published August 19th, 1919.)

The object of this invention is to provide a multiple secondary tuning with the object of completely eliminating disturbances arising from undesired

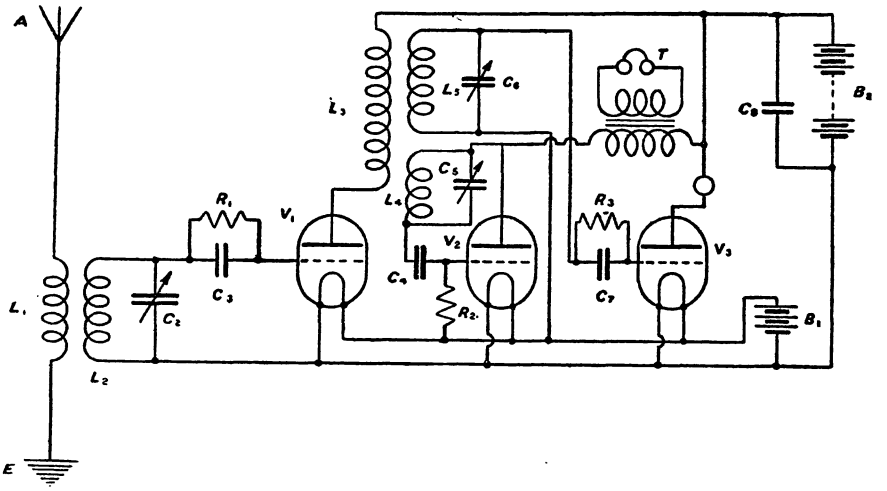

FIG. 4.

signals and from atmospherics. A number of successive secondary selections can be effected in this manner but generally two are sufficient. One typical circuit diagram is given in Fig. 4.

192. CRYSTAL DETECTOR. Perret-Maisonneuve. (*French Patent* 494882, filed January 4th, 1918. Published September 20th, 1919.)

This patent relates to a crystal detector in which the exploring point is moved in conjugate circles; the point carrier is mounted in an elastic sheath and compensation for wear is provided. The arrangement is such that the apparatus may be dismantled by unscrewing a single screw.

193. SELF INDUCTANCE. Lucien Rouzet. (*French Patent* 495037, filed June 15th, 1919. Published September 26th, 1919.)

This patent relates to a regulatable self-inductance for high-frequency circuits.

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194. WIRELESS IN THE A.E.F. L. R. Krumm and W. H. Taylor. (*Wireless Age*, 6, pp. 11—18, September, 1919; pp. 9—21, October, 1919.)

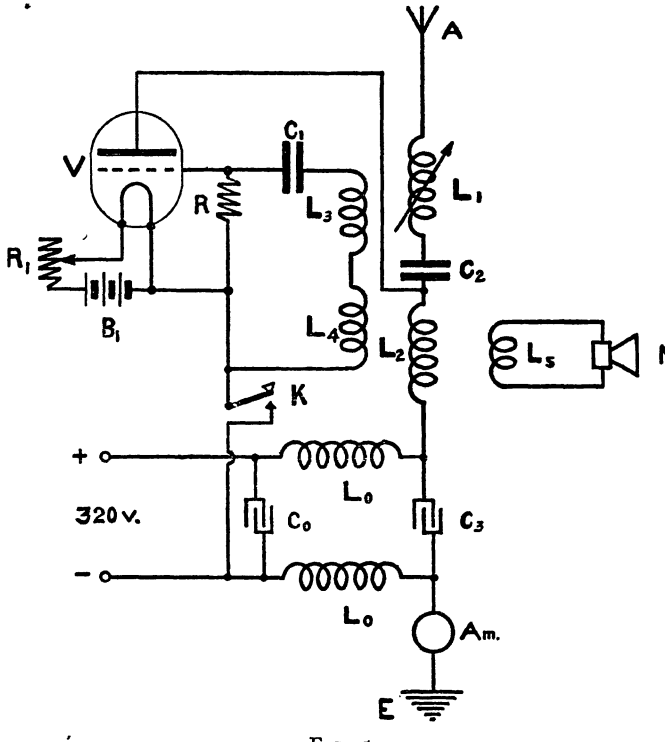

FIG. 5.

A general account of the radio activities of the American Expeditionary Force.

In the second article the general layout of the radio communications in France is given with considerable detail of the circuit diagrams of the amplifiers and other apparatus used. The transmitting connections for the radiotelephone are indicated in Fig. 5. The receiving amplifiers described are all of the iron-core transformer coupled type for low frequency magnification.

195. IMPROVEMENTS RELATING TO TELEGRAPHIC AND OTHER INSTRUMENTS AND INSTALLATIONS. J. Hettinger and C. A. Vandervell. (*British Patent* 130368, January, 1918. Patent accepted, August 7th, 1919.)

Relates to an optical indicator for multiplex telegraphy or radiotelegraphy. Other electrical applications are also mentioned.

196. IMPROVEMENTS RELATING TO ELECTRIC RELAYS. L. B. Turner. (*British Patent* 130408, February, 1918. Patent accepted, August 7th, 1919.)

The application of a three-electrode valve to serve as a relay. Use is made

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of the change in anode current when the tube starts oscillating. The grid potential is adjusted to a point just below the value necessary to cause the oscillations to start. A small external P.D. applied to the grid causes the oscillations to commence and an ordinary relay in the plate circuit to be operated. The signalling impulse may be amplified by three-electrode valves in the usual manner, before it is applied to the grid of the relay valve.

197. IMPROVEMENTS RELATING TO RECORDING APPARATUS FOR ELECTRIC CURRENT IMPULSES. The General Electric Co., U.S.A. (*British Patent* 130762, August, 1918. Patent accepted, August 7th, 1919.)

A photographic recorder for wireless signalling systems comprises a tuned reed mounted between two permanent magnets and operated upon by signalling currents which pass through windings surrounding the reed. The reed operates a mirror mounted upon a shaft, and the light from two lamps is reflected by the mirror to pass through two slits. One of these serves for adjustment only, while the sensitive paper is moved past the second. The complete apparatus comprises developing and fixing tanks in addition to the electrical mechanism.

198. IMPROVEMENTS RELATING TO WIRELESS SIGNALLING SYSTEMS. The General Electric Company (U.S.A.). (*British Patent* 130064, January, 1918. Patent accepted July 31st, 1919.)

A transmitting aerial system comprises a primary aerial supplied by a high frequency source and a number of secondary aerials supplied with high frequency current by a transmission line from the primary aerial. In an alternative construction a long horizontal aerial system is used connected to earth through tuning inductances at a number of points along its length. The object of the arrangement is to set up in the aerial stationary waves of adjustable length. By altering the ratio of the wave length of the stationary wave to the wave length of the wave that is radiated, the whole arrangement may be made non-directive, or directive in any particular direction as desired. Inductance may be inserted in the leads between the tops of the aerials so as to displace the phase of the oscillations in the successive aerials and so aid the desired directive effect.

199. AERIAL ARRANGEMENTS FOR LONG WAVELENGTHS. Société Française Radioélectrique. (*French Patent* 493609, October, 1916. Published August 14th, 1919.)

In order to increase the inductance of the aerial it is proposed to insert inductance coils at intervals along the lengths of the wires.

200. IMPROVEMENTS IN WIRELESS TELEGRAPH TRANSMITTERS. C. S. Franklin and Marconi's Wireless Telegraph Company. (*British Patent* 128983, September, 1917. Patent accepted July 10th, 1919.)

Wireless telegraph transmitters of the coupled circuit type, particularly

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those designed to emit very short waves, have the condenser, spark gap, and inductance of the primary circuit arranged symmetrically about a common axis. The antenna consists of one or more metallic rods arranged parallel to the axis of the transmitter, the closeness of the coupling depending upon the position of the rods. Alternatively a metallic cylinder enclosing the whole apparatus may serve as the antenna.

201. PHOTOPHONES. F. Tavani. (*British Patent* 128831, November, 1918. Patent accepted July 3rd, 1919.)

In photophones and similar apparatus in which selenium cells are employed, the effects of lag in the selenium are diminished by a mechanical arrangement for periodically substituting a fresh cell for the cell normally in use. The cells out of use can recover their sensitiveness in the dark, and it is claimed that as a result much more rapid response to the fluctuations of the incident beam may be obtained by this arrangement.

202. IMPROVEMENTS RELATING TO WIRELESS SIGNALLING SYSTEMS. The General Electric Company (U.S.A.). (*British Patent* 130090, January, 1918. Patent accepted July 31st, 1919.)

An arrangement for duplex wireless signalling using a separate transmitting and receiving aerial at each station. The effect of the emitted waves on the adjacent receiving aerial is neutralised by connecting the transmitting aerial to the receiving circuits by an arrangement of condensers or by electromagnetic coupling, or both. One arrangement is shown in Fig. 2, of RADIO REVIEW Abstract No. 75.

203. NAVAL RADIO REMOTE CONTROL. P. H. Boucheron. (*Scientific American*, 121, p. 234, September, 1919.)

On account of the large increase in traffic being received at the New York wireless stations, arrangements have been made for a central control station to supervise the whole of the radio communications of the port. The following stations are affected: Montauk, Long Island (NAH1); Fire Island, Long Island (NAH2); Rockaway, Long Island (NAH3); Brooklyn Navy Yard (NAH4); Bush Terminal, New York City (NAH5); Sea Gate (NAH6); and Mantoloking, N.J. (NAH7). Each station is told by the control which calling vessel it is to communicate with, or any station may be directly operated by remote control apparatus from the control station.

204. INTER-IMPERIAL COMMUNICATION THROUGH CABLE, WIRELESS AND AIR. C. Bright. (*Electrician*, 83, pp. 441—442; 464—466, October, 1919.)

205. TELEPHONE RECEIVERS. André Bloch. (*French Patent* 494654, filed April 20th, 1917. Published September 16th, 1919.)

This patent relates to telephone receiver head-dress.

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206. INTERRUPTER. E. Abegg. (*French Patent* 494908, filed January 20th, 1919. Published September 24th, 1919.)

This patent relates to an interrupter in which the elements are formed of flexible material having about the same elasticity as rubber, and are adjustable by means of a button so that they transmit movement to the movable contacts. The elastic material may be reinforced by metal springs. The moving contacts are carried on revolving arms mounted on the spindle of the interrupter, and connected to one extremity of a cylinder of elastic material which surrounds the spindle, and which is connected at its other extremity to means to cause it to turn in steps after a tension has been produced in the said cylinder by the rotation.

207. THE CONTROL OF A TORPEDO BY HERTZIAN WAVES FROM AN AEROPLANE. R. Martin. (*French Patent* 493731, December, 1916. Published August 20th, 1919.)

The wireless receiving arrangement attached to the torpedo controls through the medium of relays the movements of the steering and other motors and the ignition of the firing fuses.

208. MOVEABLE APPARATUS CONTROLLED BY ELECTRIC WAVES AND SUITABLE FOR USE IN WARFARE. G. de Trarrazaval. (*French Patent* 493137, November, 1917. Published July 31st, 1919.)

Engines for use in warfare provided with explosives, etc., and under the control of electric waves from a distant point.

209. A METHOD OF MEASURING WITHOUT ELECTRODES THE CONDUCTIVITY AT VARIOUS POINTS ALONG A GLOW DISCHARGE AND IN FLAMES. Balth. van der Pol. (*Philosophical Magazine*, 38, p. 352, September, 1919.)

The method of measurement used in the course of these researches depends on the production of stationary waves along a Lecher system of parallel wires.

210. ELECTRIC SIGNALLING APPARATUS. Oliver Arc Lamp Company, Ltd. (*French Patent* 494608, filed April 20th, 1917. Published September 13th, 1919.)

This patent corresponds to the British Patent No. 104077, and relates to apparatus employed in electric signalling.

211. THE METEOROLOGICAL TELEGRAMS OF THE EIFFEL TOWER. (*La Nature*, 47, Supplement p. 165, November, 1919.)

Full particulars of the messages and of the codes used, as revised March, 1919.

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2. Review of Books.

TEXT BOOK ON WIRELESS TELEGRAPHY. Vol. I. GENERAL THEORY AND PRACTICE. By Rupert Stanley, B.A., M.I.E.E. (London: *Longmans, Green & Co.* Pp. xiii. + 471. Price 15*s.* net.)

The first edition of this book was published in September, 1914; it was in a single volume. The subsequent development of the thermionic valve has led the author to issue this second edition in two volumes, the first covering much the same ground as the earlier edition and the second devoted entirely to the thermionic valve and its manifold applications.

The book is of the non-mathematical type and the author assumes that the reader has a very limited knowledge of mathematics and no knowledge of electrical science. The earlier chapters are devoted to an elementary explanation of the nature of matter, electric and magnetic fields, potential difference, etc. We are sorry to see that both here and throughout the book the author ignores the recommendations of the International Electrotechnical Commission with regard to symbols; this is a serious defect in a book intended for students and is sufficient to deter many teachers from recommending it. The specific resistance of copper is given as 0·00000066; is the reader not expected to know the meaning of 10^{-6} or is it given in this form to exercise him in counting noughts? On pages 77 and 78 Spielrein is misspelt Spielman. The usual formula is given for the inductance of a straight wire l cms. long and d cms. diameter, with the usual absence of any explanation or warning. Successive chapters are devoted to capacity effects and condensers, induction effects, induction coils, alternators and transformers, oscillatory discharges. In Chapter X. the author gives an account of the historical development of radio-telegraphy. The quenched spark is attributed to Wien without any reference to Lepel, although full justice is done to the Lepel system in a subsequent chapter. There is little doubt that, although Wien first clearly understood and explained the quenching action, the type of gap was due to Lepel. One is surprised to read that "in 1913 the Lieben and Reisz valve relay with three electrodes was produced and *about the same time* Dr. de Forest patented a similar thing in the Audion valve." Dr. de Forest's three-electrode valve patent was applied for in 1907 and published in 1908. A chapter is devoted to the effect of tight coupling in spark transmitters, the meaning of decrement, etc. Chapter XII. deals with the propagation of electromagnetic waves. Fig. 81 would be improved by indicating the directions of the magnetic lines by crosses and dots. When describing the radiation from the aerial the author states that "as the strain effects move outwards through the ether, they will also *probably* penetrate upwards in it." There is an unnecessary air of uncertainty about this.

The effects of the resistance of the earth and the conductivity of the upper atmosphere are considered in a simple but clear manner. Various spark transmitting sets are described and the subject of resonance in the charging circuit is considered. A number of practical hints are given dealing with

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faults in transmitting sets. Fig. 94 showing a quenched spark-gap is unfortunately upside down.

Various types of aerials, insulators, etc., are described and Howe's method is given for calculating the capacity of aerials.

Very full descriptions are given of various types of detectors and receiving circuit arrangements. A chapter is devoted to the various methods of producing continuous waves. In describing the discovery of the musical arc, the actual date would be far preferable to the erroneous statement obviously carried over from the first edition that it took place fourteen years ago. Arc generators are now made for much greater power than 100 kilowatts.

After dealing with miscellaneous apparatus such as direction finders, buzzers, etc., a chapter is devoted to high-frequency measurements. The final chapter is a new one on accumulators.

At the close of each chapter is a useful collection of exercises by which the student can test his knowledge of the subject.

This volume can be recommended to any one wishing to obtain a good working knowledge of the subject without going into any mathematical theory.

G. W. O. H.

TEXT BOOK ON WIRELESS TELEGRAPHY. Vol. II. VALVES AND VALVE APPARATUS. By Rupert Stanley, B.A., M.I.E.E. (London: *Longmans, Green & Co.* Pp. viii. + 357. Price 15*s.* net.)

Mr. Rupert Stanley is to be congratulated on being so early in the field with Volume II. of his "Text Book on Wireless Telegraphy." Dealing as it does in great part with the three-electrode valve and its applications, the subject-matter contains much of the greatest interest, and cannot fail to hold the attention of the uninitiated reader, anxious to bridge the gap of five years' rapid development. Mr. Stanley, in his position of military instructor of wireless telegraphy with the British Expeditionary Force in France, has had most excellent opportunities of handling, testing, and comparing the various types of signalling apparatus that have come into service during the war and also of entering into what must have been a most pleasant and helpful *liaison* with the French signal service, a *liaison* which has clearly had a very powerful influence on his thought and pen.

It is indeed refreshing to see such unstinted praise lavished on the French "Service de la Télégraphie Militaire" and its chief General Ferrié, whose portrait, admirably reproduced, forms the frontispiece of the volume. No praise can be too great and no recognition too full for this devoted little band of physicists and engineers, many of high academic rank in French universities, working under one of the most able and charming men it has been the reviewer's good fortune to meet.

Mr. Stanley has done well to draw so largely on the numerous military publications emanating from the Boulevard de Latour Maubourg.

It is impossible, however, when dealing with the general content of the

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book to refrain from drawing attention to the extraordinary reticence shown in regard to British efforts in the domain of wireless. No one relying entirely on the "Text Book" for information would for a moment suspect that any research or design had been carried out by the British Government along lines parallel to the French, since the only British apparatus mentioned—and deservedly so—is that of the Marconi Company. Yet there were, in point of fact, three large and active Government establishments working for the Navy, Army and Air Force respectively, *from which the great majority of the new wireless apparatus used in the services originated.*

The unfortunate omission on Mr. Stanley's part of any explicit reference to British official apparatus and design detracts considerably from the value of his book.

As for the detailed contents of the volume: in seventeen chapters of 350 pages the author leads us in pleasant if somewhat discursive style from a consideration of the fundamental ever present electron to the part it plays in the modern hard valve and thereafter by easy stages to the circuits, arrangements and use of the complete valve wireless set.

The first chapter deals in an extremely elementary way with electrons and atomic structures. After reading it, one wonders why the author did not seize the opportunity of discussing in detail the emission of electrons from hot bodies, a subject which is of such primary importance in the modern valve.

A few errors have crept into this opening chapter, as for example on page 3, where the very under-estimated speed of 50,000 km. per second is given for cathode rays in a hard tube, and on page 10, where a few thousand volts is given as the gas sparking potential, whereas in reality it may be even less than a hundred. It appears to the writer that it would have been better to instance the better known Rutherford-Böhr atom model rather than that of Vegard.

Chapter II. contains a good general account of the hard valve and its characteristic curves, the excellent mathematical treatment of Professor Gutton being first introduced here. It may prove a little puzzling perhaps to some readers to see on page 28 two apparently contradictory formulæ for the plate current of a valve, the one proposed by Langmuir, the other by Gutton; the difference between them is hardly made sufficiently clear. An historical inaccuracy occurs on page 34, where the relation $\frac{1}{2}mv^2 = eV$ is attributed to Dr. Eccles—as every advanced student of physics knows this very formula was used more than a quarter of a century ago by the pioneer workers on the ratio e/m for an electron long before the advent of the valve.

Passing on to Chapter III., the detecting properties of a valve and its associated circuits are here described along orthodox lines.

There is some ambiguity in the wording at the top of page 40, where the author in explaining that no rectification can occur when working on the straight part of a valve characteristic appears to leave the erroneous impression that the slope must be 45°.

Mr. Stanley throughout the book recognises the power of the graphical method in explaining qualitatively valve properties and in this chapter uses the method. But in proving, on page 46, the very important proportionality

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relation between extent of current rectification and the square of the potential oscillation a general function is expanded by Taylor's theorem and high terms in the expansion neglected. A much simpler proof involving in the long run the same assumptions, and one often more convincing, can however be arrived at geometrically; for if we approximate and suppose that the characteristic bend is an arc of a circle, of radius R, then it follows at once from the well-known rectangle property of a chord bisected by a diameter at right angles, that $2R \times$ (small current change) = (potential change)^2 which is, of course, the desired relation.

Chapter IV. deals with the various methods of amplifying high frequency oscillations. It is not clear why the author separates this chapter from the seventh, which (in a more natural position following the section on oscillations) deals with the same subject.

The two chapters together are rich in excellently drawn standard circuit diagrams, well explained. Insufficient stress however seems to have been laid on the real object of high frequency magnification which is to increase the oscillation amplitude until rectification can be efficiently applied. The British official types of instrument are here, as elsewhere, omitted.

Chapter V. gives a further instalment of Professor Gutton's mathematical treatment of the valve, now regarded as an oscillator.

Chapter VI. deals with the use of the valve in low-frequency amplifying apparatus and the standard iron core transformer circuits are clearly described. The author apparently considers that the terms "relay" and "amplifier" are synonymous and interchangeable, a point of view which can, in the present writer's opinion, only lead to confusion of thought. It would be convenient to reserve the term "amplifier" for instruments which reproduce a more or less faithful copy on a larger electrical scale of an initial varying current or potential—in this class would fall all the valve amplifiers described in Mr. Stanley's book.

The relay class would include such instruments as the Post Office relay and the electromagnetic key.

The value of the chapter would have been enhanced had the author explained the standard method of measuring the amplification produced by a polystage amplifier; mention might also have been made of the possibility of constructing low-frequency amplifiers using condenser connections between the valves instead of transformers.

Chapters IX. to XI. give a good though incomplete account of some standard types of valve.

Chapters XII., XIII. and XIV. discuss the general arrangements and working of continuous wave and telephone sets, with particular reference to those sets which the author has himself used. These chapters are less complete than many of the preceding ones, particularly in the section dealing with telephony. Some interesting photographs are added to the numerous diagrams.

Chapter XV. is a short semi-historical survey of the development of high frequency transmitters and is interesting in spite of being outside the true scope of the book.

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The chapter includes in passing references to H.F. alternators and methods of microphonic control of oscillating currents, but it is disappointing not to see here even a short account of the very interesting two-wave system.

Chapter XVI. gives a very practical account of the earlier earth signalling apparatus using buzzer and amplifier. The Government Fullerphone, which has revolutionised earth signalling, is not mentioned.

The last chapter contains a few short and disconnected accounts of various apparatus not included in previous chapters, such, for example, as the heterodyne wavemeter, the telephone "repeater," the generation of short wavelengths and some others.

In conclusion it is the feeling of the reviewer that in spite of the many small mistakes that have crept in, and the very regrettable omissions, the book will prove useful to those seeking a general acquaintance with the subject.

It is clearly printed on good paper, with a large number of excellently reproduced diagrams in the text, and like other books by the same publishers is singularly free from printer's errors.

R. WHIDDINGTON.

Correspondence.

ON THE GONIOMETRIC FUNCTIONS APPLICABLE TO DIRECTIVE AERIALS.

TO THE EDITOR, THE "RADIO REVIEW."

SIR,—I have examined the October, 1919, issue of the RADIO REVIEW and desire information concerning the first and second pages of the issue on which reference is made to *British Patent* 15527 of July 11th, 1902, to A. Blondel, with the statement that this patent refers to radio-goniometric closed coil frames.

On examination of this patent it is not seen that the specification relates to coil antennæ.

On page 2, reference is made to *German Patent* 237,486 of January 15th, 1910, as describing the use of coil antennæ. This number does not refer to a radio patent and information is requested concerning the correct citation.

J. B. BRADY.

Navy Department, Bureau of Steam Engineering,
Washington, U.S.A., *November 19th*, 1919.

TO THE EDITOR, THE "RADIO REVIEW."

SIR,—In your October issue, on page 1, M. Blondel states in a foot-note that his *British Patent* No. 15527 of July 11th, 1902, discloses "the use of a closed frame for radio-goniometric purposes." I have carefully examined this patent, but am unable to find any drawing or description therein which warrants such a statement. The patent cited is in fact for a system of radio-telephony, and so far as any aerials are shown or described, they are of the ordinary elevated-conductor-and-ground type.

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In a continuation of the above foot-note, on page 2, M. Blondel attributes to himself, as of the year 1908, the use of " these frames closed by a condenser," and gives certain other dates, all apparently as a brief history of the loop aerial radio compass. Although I dislike to trespass on your valuable space in a mere matter of priority, M. Blondel's bibliography is so inaccurate (as pointed out above) and incomplete as to demand correction.

My own early publications dealing with the radio compass are given below, and so far as I am aware they are the first to describe adequately a coil or loop aerial, tuned by a series variable condenser and operating independently of a ground connection.

" An Ungrounded, Closed Circuit for Receiving Wireless Signals," *Electrical Review*, New York, June 15th, 1907. See also editorial note in the same issue. An abstract of this article appears in the London *Electrician* of July 19th, 1907.

United States Patent No. 876996, filed June 10th, 1907, and issued January 21st, 1908. In addition to showing an ungrounded loop aerial, tuned by series capacity, this patent also discloses for the first time the combination of open and closed aerial reception, often though erroneously attributed to MM. Bellini and Tosi.

" Determination of Wireless Wave Fronts." *Electrical Review*, New York, October 3rd, 1908. This is an illustrated article, showing a multiturn ungrounded loop, one meter in diameter, employed as a portable radio compass.

United States Patent No. 956165, filed September 3rd, 1907, and issued April 26th, 1910. This patent shows loop aerials, separated on centres by thousands of yards, and coupled by way of phase adjusting means to a common or central secondary circuit. It is of passing interest to note that this is the arrangement employed by Weagant, and shown in Fig. 4, page 50, of the October RADIO REVIEW.

GREENLEAF WHITTIER PICKARD.

Newton Centre, Mass., U.S.A.
November 26th, 1919.

The above letters have been submitted to M. Blondel, who has replied as follows:—

TO THE EDITOR, THE " RADIO REVIEW."

SIR,—Replying to your letter I beg to submit the following corrections to the citations given in my paper in the RADIO REVIEW* :—

Instead of *British Patent* 15527, July 11th, 1902, read *British Patent* 11427/1903, Fig. 7.

Instead of *German Patent* 237486, read *German Patent* 237456, January 15th, 1910, page 5, lines 88 to 105.

A more complete list of references to my patents and work on directive aerials follows :

" The constitution of simple frames with two conjugate aerials " was first

* RADIO REVIEW 1, foot-note to pages 1 and 2, October, 1919.

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described by me in 1902, *Belgian Patent* of May 28th, 1902. *British Patent* 11427 of 1903 covers practically the same subject-matter. The same arrangements were made the object of a publication in the form of a Memoir presented to the Congress of the French Association for the Advancement of the Sciences, at Angers in 1903, Memoir No. 138562, page 11 of the reprint; the closed frames are there described on page 16. Tests made on the Blondel type of closed frames were described in the notice of the French Minister of Public Works on the apparatus exhibited by the Service des Phares Français at the Franco-British Exhibition in London and at the Exhibition in Marseilles—Fig. 5, on page 94 of that Notice, to which the second half of page 93 refers, indicates the dimensions given to the directive closed circuit frames.

The experimental researches on these Blondel frames were carried out by le Capitaine du Génie Ferrié, and the installations by Lieutenant Brenot. It is shown in the test records held by the latter that the frame comprised several closed turns, short-circuited by a capacity, and that in this closed circuit sometimes half-wavelengths and sometimes complete wavelengths were obtained.

A fresh reference to this arrangement was made in a *German Patent* (A. Blondel) No. 237456 of January 15th, 1910, page 5, lines 88 to 105. In March, 1910, in collaboration with Captain Brenot, with the assistance of Mons. Polak and under the direction of General Ferrié, I took up the study of closed frames comprising several turns oscillating in complete waves, the circuit being closed by a capacity. To obtain the required sensitiveness the necessary dimensions of these frames were unfortunately very large, but in October, 1915, General Ferrié conceived the idea of combining an amplifier with them, thus enabling a considerable increase in sensitiveness to be obtained, and the dimensions of the frame to be reduced so that it could be freely turned about a fixed axis.

There is also *Belgian Patent* No. 169746, "Improvements in Receiving Apparatus for Wireless Telegraphy and Telephony" covering the Thermo-electric Receiver and the Monotelephone which I invented; and *American Patents*, Nos. 824682, and 783992, both of February 7th, 1905, relative to the use of musical waves for the selection of signals.

Finally, there is my *United States Patent* No. 1218237 of November 4th, 1913, for "A Method of determining the Direction of a Wireless Station ('phare')."

A. BLONDEL.

Paris.
December 10th, 1919.

THE ELIMINATION OF MAGNETO DISTURBANCE.

TO THE EDITOR, THE "RADIO REVIEW."

SIR,—In this month's RADIO REVIEW, Captain Robinson refers to the fact that, by choosing suitable valves, magneto disturbance can be eliminated by adjusting the filament current to a certain value—depending of course on the valve in use. Might I offer a possible explanation?

The capacity between grid and filament together with their inductance and

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that of the connections, if adjusted carefully, provide a small oscillatory circuit of the frequency necessary to absorb the short waves received from the magneto in the same manner as the extra circuit mentioned earlier in the article. A very small change in the oscillation constant of such a short wave circuit is enough to prevent this absorption. The filament on being gradually raised in temperature, expands; this alters the capacity by placing more surface in contact with the dielectric and by setting the filament nearer to the grid. At a certain point the capacity reaches the required value and "tunes out" the disturbances. Further increase in the filament current throws the circuit again out of tune, and the disturbance reappears. The rather sudden action would be accounted for by the sharpness of tuning at such high frequencies.

The slightest differences between valves would be sufficient to throw the range of tune outside that required; *e.g.*, the grid support is often of two wires twisted together. If the flux used in soldering to the seal worked between these wires it would give a different value to $\sqrt{LC}$, enough to destroy the required action. It would be interesting to know whether this action of a valve persists or whether the "tuning current" requires to be of larger value as the filament gets "worn thin." The rheostat used, too, might make it impossible to get the required values of current exactly; the best form of filament rheostat would appear to be a continuously variable one, such as the form in which carbon blocks are compressed by a screw.

L. J. Voss.

Plympton, Devon.
December 18th, 1919.

"THE THERMIONIC VALVE AND ITS DEVELOPMENTS IN RADIOTELEGRAPHY AND TELEPHONY."

To the Editor of the "Radio Review."

Sir,—I have just read the last volume of Professor Fleming on the thermionic valve. I am extremely surprised that Professor Fleming does not mention any French name among those of engineers who have studied the three-electrode valves.

(1) After Dr. Langmuir had published the curves of plate current and grid current in the *General Electric Review* of May, 1915, I published myself, before anybody else, in the *Electrician* of December 1st, 1916 (see also my *British Patent* No. 127318 of April 15th, 1916), the very simple mathematical theory of the operation of the three-electrode valve based on the knowledge of the slopes of these curves. This my theory is now classical and has been reproduced, and possibly developed, by different authors (Hazeltine, van der Bijl, Carson, Ballantine, etc.). But having myself an obvious priority founded on a *British* publication, I feel naturally very much surprised that Professor Fleming does not mention my name at all when writing on the mathematical theory of the three-electrode valve.

(2) Referring to resistance amplifiers, I beg to call attention to the fact that these amplifiers have been first used and patented by French engineers

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(*French Patent* of Péri, February 1st, 1916; *French Patent* of Beauvais and Brillouin, March 20th, 1916).

(3) Referring to high-frequency amplifiers with iron-core transformers, I have been the first to consider them (see my *British Patent* No. 127318), and have furnished a large number to the British forces during the war. I cannot admit that the use of iron powder (as known for loading coils) instead of sheet iron changes anything in the principle. Furthermore, the tuning at every stage with iron-core transformers, as in the amplifier No. 55 of the Marconi Company (see Fig. 131 of the volume), is described in my *British Patent* No. 130056.

I have published in the *Electrician*, of May 16th, 1919, the very interesting results obtained with tuned high-frequency amplifiers with iron-core transformers of my construction.

(4) It may be that Professor Fleming, the inventor of the valve, has also designed three-electrode valves according to Fig. 67 of his volume (page 128), but as a matter of fact this type of valve is known as the "French valve" and covered by the *British Patent* No. 126658 of Biguet and Péri.

MARIUS LATOUR.

Paris,
December 29th, 1919.

The above letter has been submitted to Professor Fleming, who has replied as follows :—

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—M. Marius Latour expresses his extreme surprise to you that I have not made reference in my book on "The Thermionic Valve" to certain French patents or to a paper by him in the *Electrician* of December 1st, 1916. Considering that the said patent specifications or their British equivalents were not open to public inspection at the date when most of my book was in print it would have been still more surprising if I *had* mentioned them. As regards his paper on which he lays so much stress, owing to pre-occupations, I did not happen to notice it at the time it was published, or if I did, I failed to make a note of it, as I had then no thought of writing a book on the subject.

Having now, however, looked at this paper, I must confess I do not think his treatment of the subject in it is so epoch-making or novel that all other writers on the theory of the three-electrode valve should consider themselves as anticipated by, or under debt to it. The discussion of the problem in my book taken from the papers of Vallauri, Hazeltine, van der Bijl, and Ballantine, with simplifications of my own is, in my view, more elucidatory than that of M. Latour. If, however, the opportunity occurs of mentioning his contribution to the subject in a second edition of my book, I shall be pleased to do it, although I cannot share his opinion as to its fundamental importance. As regards the coupling of valves in cascade by resistance coupling or iron-cored transformers, or his assumed anticipations of any of the types of valve receiver designed and made by the Marconi Company, I must decline to be drawn into the discussion of any questions of priority. The proper place for the settlement of these questions is a court of law, and

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not the columns of a scientific journal. I have had quite enough of these controversies in the past with respect to my own share in the evolution of the thermionic valve in which the final conclusion has only been reached after judgments given by such courts.

With respect to his remark on the "French valve," I knew perfectly well in 1917 that a certain type of valve much used in the war was so called, but I intentionally abstained from making reference to it by that name, or to the origin and use of the valve figured on my page 128 for the following reasons: My book was written and almost entirely in print before the armistice was declared, and no one knew at that time when the war would be ended. It was necessary, therefore, for me to exercise a certain discretion in reference to apparatus in actual use in the field of war. Moreover, I did not consider this type of valve involved any great novelty. In 1915, I had a "hard" or high-vacuum valve made to my design, having a cylindrical anode and a spiral wire grid concentric with the cylinder.

In my laboratory notebooks I find records of experiments made with this valve on January 14th, 1916. Now the British patent application of Péri and Biguet was not made until October 23rd, 1916 (No. 15072/16), and the complete specification was not accepted until May 22nd, 1919. The specification was not open for inspection until still later. Hence information as to it was not until then public property. As I had in my possession a valve of similar construction, viz., cylinder and spiral grid, made for me ten or eleven months previously to the British patent of Péri and Biguet, I could not see any good reason for particularly nationalising this type as "the French valve," although it had many good points, such as the small bulb and convenient four-pin attachment.

In any case, the claims of the patent, even from the Convention date, would be limited to the precise form of valve figured. After all, the main question at issue is whether the author of a book shall retain the right of private judgment in the selection of his material, or whether he shall be moved by the possibility of "extreme surprise" on the part of some one if he omits to include all that other writers consider important, or to have claims to priority.

In this case my book was chiefly written during the greatest struggle in history, under a strict censorship, with patent publication mostly restricted, information closely guarded, and much knowledge carefully withheld. My object was not to give publicity to everything written by every one on the subject, but to give as lucid a description as possible of the developments and operation of the thermionic valve.

J. A. FLEMING.

London,
January 5th, 1919.

HARDENING AND SOFTENING OF IONIC TUBES.

TO THE EDITOR, THE "RADIO REVIEW."

SIR,—The alternative explanation of the changes of gas pressure in thermionic tubes elaborated by Dr. Eccles in his suggestive letter in your

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November number calls for a re-consideration of the grounds on which the older view is based, even though no observations contradictory to the former explanation be forthcoming.

The effects in question were systematically investigated by Dr. Bryan under conditions differing little from those of modern practice as long ago as December, 1914, and the conclusions then reached, namely, that increase of anode voltage is followed by disappearance of gas, and *vice versâ*, have been amply confirmed by later work both before and after the stabilisation of the vacuum by a suitable "ageing" treatment was introduced as the final stage of the manufacturing process.

Both theories therefore aim at explaining the same observed facts, and these facts may be considered well established.

Dr. Eccles puts forward the view that the gas when it disappears goes into the filament. If it does so it is no mere surface condensation that is involved, but a dense impregnation of the body of the filament with gas. An example will show this. The limiting amount of gas that can be made to disappear from the body of an ordinary small bulb of some 80 c.c. capacity is enough to produce an increase of pressure of about $\frac{1}{20}$ mm. of mercury in such a bulb. This quantity of gas compressed to atmospheric pressure would have volume about ninety times that occupied by a filament of ordinary dimensions, *e.g.* 2·2 cms. long and 0·006 cm. diameter. Again, if this gas were supposed fully condensed, with its molecules brought into contact with each other, it would occupy a volume of as much as one-fifteenth of that of the filament which, on Dr. Eccles' view, is to absorb it. Now such observations as have been made on the amount of gas given out even by a fresh piece of metal, such as nickel or tungsten, when first heated in a vacuum, hardly approach this quantity, and further, from the fact that subsequent melting of the metal need not be followed by any marked additional evolution, it seems the metal can be made to give up the whole of its gas. In face of this it is difficult to imagine a filament which is already heated to incandescence taking up so large an amount of gas as the hardening of a valve may require.

The older theory may be tested by means of the same numerical example, but before that there is a misconception, from which Dr. Eccles seems not entirely free, to be touched upon.

The effect of the rise of anode voltage in increasing the number of positive ions derived from the gas will not be large in an ordinary high-vacuum valve even though the rise be from 100 to 2,000 volts, for in the transit across the tube of such few electrons as do collide with gas molecules one collision only will occur, and in either case that collision will be sufficient to result in ionisation, both voltages being far above the critical ionising value.

It is not, therefore, the anode voltage, but the chance of collision that chiefly determines the number of positives, and this chance depends at a given pressure on the length of path traversed by the electron. Those electrons that travel from cathode to anode by a circuitous route will stand the most chance of colliding. On the older theory this is clearly a point of importance. Many of the positives will be formed in the outer regions of the bulb, and in the cases of puncture cited by Professor Fortescue and Dr. Bryan these ions

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used to give visible evidence of their undesirable presence by local patches of glow. The fate of such ions is much more likely to be impact on some part of the walls of the tube than on the cathode. Such impacts are of a violence far beyond that of the ordinary impacts to which the pressure of the gas is due, but otherwise little is known of their nature. It seems, however, far more likely that such ions will become permanently embedded in the cold walls than that those which strike the incandescent cathode, the surface of which has a very small area, and is also in a state of relatively violent temperature agitation, will remain there.

Nor is the quantity of gas previously considered in any way excessive for retention by the walls. On the contrary, if spread uniformly over them it would be only a trifle more than enough to form a layer a single molecule in thickness. The probable existence of such layers, and their stability when formed is generally recognised. It is thus scarcely necessary in the case considered to assume that the gas must be able to penetrate into the body of the glass.

It seems reasonable to interpret the following observation, recently made in this laboratory, as a visible demonstration of the existence of such a surface layer. If a valve which has been freed from gas to the normal extent by thorough bombardment of the anode is allowed to cool, and then a trace of gas is admitted, *e.g.*, by heating to the softening point a part of the exhaust stem, the anode may present a very curious appearance when bombardment is resumed. The surface of the anode is seen to be covered with a very thin uniform film of blue glow, like the bloom on a fruit, and this without the appearance of any trace of glow in the body of the tube. As the anode heats the glow disappears, and does not appear again on repetition of the bombardment, unless more gas has been admitted in the meantime. The effect occurs in spite of the valve being connected to a diffusion pump throughout the experiment. This peculiar glow would appear to come from a film of gas "*ad*sorbed" on the cold nickel surface, and there ionised by the impinging electrons. Similar effects have been observed at the surface of fresh glass, but were ascribed to a fugitive fluorescence.

Consideration of relevant facts additional to those taken into account by Dr. Eccles in his letter thus inclines to the support of the older view of the physical phenomena involved.

There is a point that appears obscure in the bird's-eye view of the normal working of the valve given in the earlier part of the letter—"The electron flow will be sufficient to prevent the positive ions reaching the cathode in any considerable numbers." Now can the electron flow produce such an effect? It might certainly do something of the kind either by deflecting the positive ions from their path towards the cathode, or by combining with them, destroying their ionic property, and re-constituting ordinary uncharged gas molecules, of which a great excess is present already.

But to what extent can either of these effects be supposed to be going on? In the first case, the momentum of the positive as it comes up to the neighbourhood of the filament is greater, many thousands of times greater, than that of the electrons in that region, both by reason of its greater mass and

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by reason of the much greater velocity acquired since its formation. Hence if the motion of the positive is to be reversed not one, but hundreds of collisions must take place, and we must imagine an electron atmosphere near the cathode of a very high density, relatively to the residual gas, for instance. The requirements for re-combination are similar, though less in degree. Here also the velocity of the positive must be reduced in some way to a value comparable at most with the ionisation voltage of an ordinary gas, ten to twenty volts or so.

The question is therefore one of the density of the negative space-charge at various distances from the filament outwards, and is one that is easier to state than to follow up analytically even did your space permit. An investigation of the matter would make clearer and more precise our mental picture of the physical conditions in one of the most important regions in the valve.

B. S. GOSSLING.

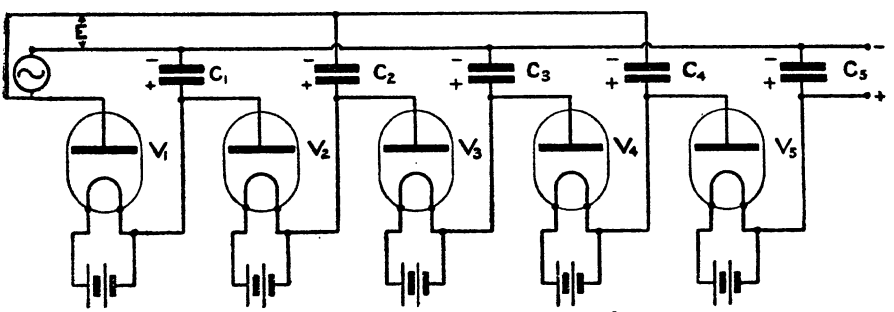
The Research Laboratories of the General
Electric Company, Hammersmith,
January 10th, 1920.

(Owing to pressure of space some correspondence has been unavoidably held over.—ED.)

ERRATA.

Page 182, *Fig.* 1. *Transformer* T_1 T_2 *should be a step-up one similar to* T_3 T_4.

Page 194. *Fig.* 5 *has been incorrectly drawn. The proper arrangement is indicated below:*



Page 208, *Fig.* 12. *A connection should be taken from the negative side of* B_1 *to the wire immediately below it*—i.e. *connecting together the negative terminals of* B_1 *and* B_2.

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THE
RADIO REVIEW

VOL. I MARCH, 1920 NO. 6

A Method of Direction Finding of Wireless Waves

And its Applications to Aerial and Marine Navigation.

By Capt. JAMES ROBINSON, R.A.F., M.Sc., Ph.D.

(*Continued from page* 219.)

4. AMBIGUITY.

In the minimum method of determining the direction of incoming waves there is always the ambiguity of 180°, and if a bearing θ is obtained it is uncertain whether the transmitting station lies in the direction $\theta°$ or $(\theta° + 180°)$.

The present system, when looked at casually, might be supposed to increase this uncertainty, so that one cannot be sure whether the bearing is $\theta°$, $(\theta + 90)°$, $(\theta + 180)°$ or $(\theta + 270)°$. However, on closer observation the two directions $(\theta + 90)°$ and $(\theta + 270)°$ are out of the question.

The reason why it may be considered to give this uncertainty of four directions is that, if the correct bearing is obtained, the signals are of equal intensity. At 90° from this direction it is obvious that the signals, on reversal, are also of equal intensity. The system of connections in use, however, makes it possible to find whether, when using the main coil alone, a signal can be heard. When on the correct bearing a signal will be heard when on the main coil alone, and this will be of the same intensity as the equal signals when both coils are used if, as is usually the case, the dampings are the same when one coil or both coils are used. When on the positions which are 90° out no signal will be heard on going over to the one coil position. It is impossible to make this error of 90° if the method for finding a bearing as described

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above is followed, where an approximate determination of the maximum of the main coil is first obtained.

There is another obvious method of knowing whether one is on the correct bearing or 90° out. In practice, the coils are used with the area-turns of the auxiliary coil two or three times that of the main coil. Hence, when on the correct bearing, the set is very sensitive, and, when on the position 90° out, the set is very much less sensitive, it being necessary to move the coils 5° or more without making any appreciable change in the intensity of the signals on reversal.

5. General Application of the Method.

So far the method has only been described in its relations to rotating aerials, but it is capable of application to any minimum method of direction finding. In the case of the Bellini-Tosi system, where the moving part is a small coil inside the instrument, known as a radiogoniometer, the same effect is obtained by rotating this moving coil through 360° as is obtained by rotating a single loop aerial through 360°. It is only necessary to construct a radiogoniometer with two movable coils fixed rigidly at right angles to each other, so as to have no mutual induction, one of them to be equivalent to the main coil in Fig. 1, and the other to the auxiliary coil. Fig. 4 shows the connections.

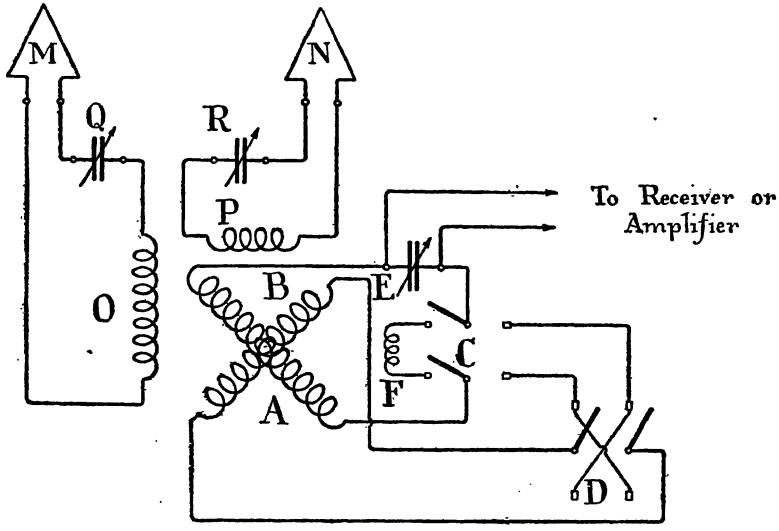

FIG. 4.

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M and N are the fixed aerials at right angles to each other. O and P are the fixed coils of the radiogoniometer. Q and R the aerial tuning condensers. A and B are the two movable coils rigidly fixed together. A corresponds to the main coil, B corresponds to the auxiliary coil, C is the change-over switch, and D the reversing switch, as in Fig. 1, F being the balancing inductance. For a workable sensitiveness the area-turns of B will be made two or three times those of A.

Another method of applying this system to the Bellini-Tosi method is to use two distinct radiogoniometers with the movable coils capable of rotation together. The radiogoniometers should not have any influence on each other. The moving coil of one will form the main coil, and that of the other the auxiliary coil.

6. D.F. ON AIRCRAFT.

The method of direction finding which has just been described is suitable for application to aircraft, and in fact was designed originally for this purpose. The conditions on aircraft are such that a minimum method would be inaccurate, as the external noise of the engines makes it impossible to hear weak signals. With a minimum method, the region in which the signals are inaudible is much wider than in similar conditions on the ground, and thus on aircraft it would be much more inaccurate.

Directional wireless is of the first importance for aircraft for the purpose of navigation. The problem of navigation of the air presents many features different from those at sea. One that stands out clearly is dead reckoning. At sea it is possible to use dead reckoning methods, by knowing the course steered and the distance travelled. In the air, however, the course steered may be quite different from the course made good, and the air speed is no criterion for the ground speed, because of the unknown factor of drift. Hence the importance of the determination of position by any possible method, or failing that, the finding of directions on fixed places from time to time. The problem of aerial navigation is vast, and it is only proposed here to indicate how this method of direction finding acts as an aid to it.

(A). We shall first consider the case of an aeroplane making for a spot where there is a wireless station, which transmits from time to time. In such a case the D.F. aerials can be fixed to the aeroplane and the aeroplane turned to get its head on to the

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station. This method of applying the D.F. system, we shall call the *wing coil method*, as the aerials can be most conveniently fitted to the wings.

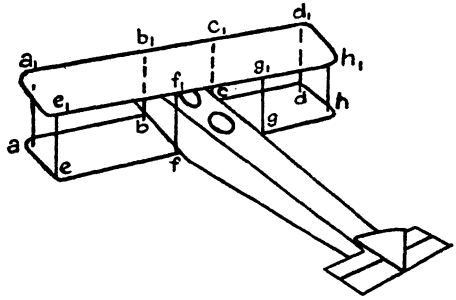

FIG. 5.

Fig. 5 shows how the coils can be conveniently fitted. We take the case where there are two pairs of struts on each side of the fuselage, aa_1, bb_1, cc_1, dd_1, being the struts near the leading edge and ee_1, ff_1, gg_1, hh_1, those near the trailing edge. The main coil is the coil whose maximum is to be determined and it must be fixed so that its plane is in the fore and aft line of the aeroplane. The auxiliary coil is then fixed with its plane athwartships. The main coil is usually fixed in two parts, one on each side of the fuselage, *i.e.*, some turns on the struts aa_1, ee_1, and some on the struts dd_1, hh_1. The auxiliary coil may be in one part only, either on the leading or trailing edges, *i.e.*, up hh_1, along the upper wing to e_1, down the strut e_1e, and along the lower wing to h. Again the auxiliary coil may be also in two parts, a device which is suitable for aeroplanes with folding wings. Leads from the coils are brought into the fuselage. By this method it is simple to keep the head of the aeroplane pointing towards the transmitting station, and thus to find the way to the destination.

It is worth noting that if there is a cross wind, this will make the aeroplane drift from its path, and if bearings on the home station are taken at intervals, it will be found that the effect of the cross wind is to make the bearing on the home station alter continuously, and the path of the aeroplane will be curved. A skilful navigator can however get some idea of this drift from consecutive bearings and apply corrections so as to make his path much less curved.

The wing coil method can be used for determination of position if two or more wireless stations or beacons transmit so that two

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or more bearings on known stations can be found. It is necessary to turn the aeroplane towards or away from the beacons in turn, reading the compass in every case when dead on the beacon.

This wing coil system is excellent for head bearings and also for tail bearings, but it has not been used much for determination of position in the air because of the time lost in turning from one's course though good results have been obtained. Very accurate bearings can be taken by the wing coils on the ground, by having a working party to turn the aeroplane round. There appear to be no errors with the wing coils, and in every case when a bearing is obtained, the fore and aft line of the aeroplane is along this bearing, assuming that there is no error in installing the coils. Tests have been made on the ground by taking head and tail bearings on a station and recording the direction of the fore and aft line of the aeroplane in each case by an accurate magnetic compass on the ground. Within the limits of accuracy, the bearings differ by 180°. In one particular case with the ratio $k = 4$, the head and tail bearings were within $\frac{1}{4}°$ of 180°.

(B). For the more formal problem of navigation it is advisable not to have to turn the aeroplane from its course in order to determine its position, or even to determine a single bearing. Then it is essential to make the D.F. system with the moving parts capable of rotation apart from the aeroplane. This is done by installing D.F. coils on frames that can be rotated inside the fuselage. We shall refer to this system as the *fuselage coils system*. By it, bearings can be taken no matter what course the aeroplane is on, and position determined if a sufficient number of bearings be taken. The problem of working out the bearings and thence of working out position is a well-known problem of navigation and will not be gone into in detail here, but certain features that are of interest from the wireless aspect will be dealt with.

The size of coils that can be used inside the fuselage of aeroplanes is not large, even with the largest aeroplanes known at present. With the ordinary Handley Page, the framework of the coils is about 4 feet 6 inches high × 3 feet 4 inches diameter.

On smaller machines the coils are proportionally smaller and in one case coils 2 feet high and 2 feet diameter were successfully used. In any case the coils give much weaker signals than the wing coils, as the area turns are very much less.

Determination of position is similar to the method of sights

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used at sea except that for long distance bearings great circles must be considered.

The direction of the incoming waves is determined with regard to the fore and aft line of the ship, and recorded red or green for port or starboard. Knowing the course steered by the aeroplane, the direction of the incoming waves is determined. In practice certain corrections have to be applied,

(*a*) The magnetic variation.

(*b*) The deviation of the compass; and

(*c*) The quadrantal errors of the D.F. coils, *i.e.*, the angle between the direction of the waves in space and the apparent direction recorded by the coils (see below).

Great care is needed in taking these bearings, especially if the beacon is a long distance away. For a distant beacon, an error of 2° means a large error in distance. It must be remembered that it is a very difficult matter for a pilot to keep a course steady to 1° for a lengthy period. Again the navigator's compass so far used has not been perfect. Again bumpy weather makes it difficult to keep the course steady and each bump makes the compass move. Once the compass starts moving it usually takes a little time to come to rest again. A considerable amount of training is required for an observer to take a bearing by his D.F. coils and to get a reliable reading of his magnetic compass at the moment his bearing is taken.

In order to lay off a bearing on a chart it must be remembered that the path of electromagnetic waves is a great circle, and if a bearing of $\theta°$ is found on a certain beacon, this means that the aeroplane lies on the great circle passing through the beacon and crossing the meridian of the aeroplane at an angle of $\theta°$. It is found that it is possible to draw a line on a chart so that at any point on this line, the bearing on the beacon is $\theta°$. Such a line is called a *line of equal bearing*. Charts are made with these lines drawn for various beacon stations.

Quadrantal errors must be carefully determined. They vary with the direction in which the waves strike the aeroplane. They are equivalent to a deviation of the waves by the aeroplane, this deviation depending on the direction of the waves. They may be due to one of two causes, or probably to both causes :—

(*a*) Actual deviation of the waves by the metal parts of the aeroplane, more especially by the engines and tanks.

(*b*) The fact that the metal parts of the aeroplane absorb

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energy from the waves, part of which energy is re-radiated in a definite direction.

Evidence seems to point to the fact that the second cause accounts for most of the deviation.

The nature of the quadrantal errors is as follows :—

The errors are zero in the fore and aft, and athwartships direction, and a maximum at the 45° and 135° directions from the fore and aft line. A large number of different Handley Page aeroplanes showed the same characteristics, though the actual magnitude of the deviations varied somewhat from machine to machine. In most machines however, the maximum errors were 8° or 9°, though in one machine they were as low as 3°. In another type of aircraft, the flying boat, the maximum errors were 3°. These errors are independent of the wavelength so far as our observations have gone, using waves from 2,000 to 8,000 metres. The errors are usually of the same magnitude in opposite quadrants, though at times it is found that this is not the case.

The method of determining the quadrantal errors is to swing the aeroplane and take bearings on the same beacon station, every 10° or 20° as the aeroplane is rotated. Knowing the correct bearing, the errors for each position can be calculated.

7. DESIGN OF COILS FOR ANY WAVELENGTH.

(1) *Energy absorption by loops.*—The E.M.F. picked up from electromagnetic waves by a loop depends on many factors but it is always of a small order of magnitude compared with that which is picked up by an ordinary plain aerial. Attention must thus be paid to many points in order that the best possible results may be obtained. It is usually necessary to use amplifiers in order that signals may be heard at all. Careful attention must be paid to such things as insulation, good contact, and accurate tuning.

(2) The E.M.F. depends on the dimensions of the loop and on the number of turns. Within fairly wide limits it is safe to assume that the E.M.F. is proportional to the area-turns of the loop. There has been a suggestion of a possibility that this proportionality does not continue as the number of turns is increased indefinitely, and that the E.M.F. approaches a maximum value above which it is impossible to go, no matter how many more turns are used. The writer has had no experience of this and for the coils used in practice it is not far from the truth to assume proportionality

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between E.M.F. and area-turns. As many as fifty turns have been used on occasions but as a rule fewer turns are used.

One of the first points in design is that the dimensions of the coils shall be as large as permissible, and that as many turns as possible shall be used.

(3) The number of turns that can be used is limited by the fact that inductance increases almost as the square of the number of turns. In order to have good tuning, a certain condenser value must be used, this value being small. It is found in practice that there is a best condenser value for each wavelength and that very little if any advantage is obtained by increasing the number of

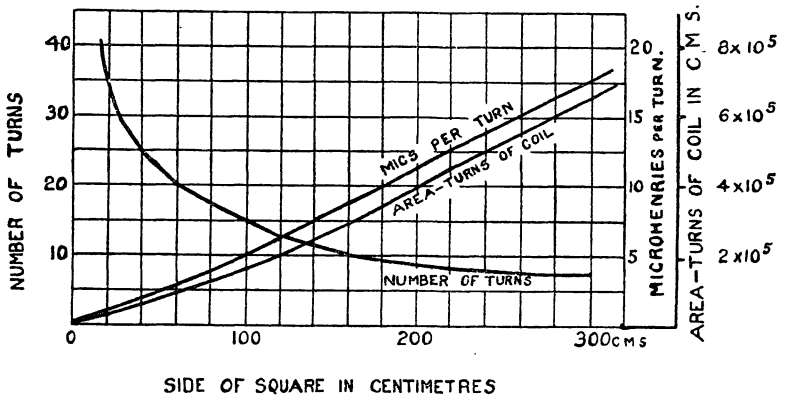

FIG. 6.

turns above that which gives this best condenser value. Another factor which limits the number of turns is the self capacity of a coil. This is of such importance that a loop consisting of a few turns has a definite wavelength when used without any tuning condenser, this wavelength being the lowest that it is possible to obtain. In order to keep the self capacity down, it is necessary to space the turns.

(4) To calculate the number of turns required for any specific conditions, *i.e.*, when the wavelength and outside dimensions of the coil are given, certain formulæ are in existence which give the inductance of a single turn of a square, rectangle or circle. Square or rectangular coils are used most, so we shall restrict ourselves to these cases. The formula which has been used for a square coil is $L = 18{\cdot}424a\left(\log_{10}\frac{a}{r} + 0{\cdot}4343\,\frac{r}{a} - 0{\cdot}3361\right)$ where $a =$ side of

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square in cms. r = radius of wire in cms. From this formula curves, shown in Fig. 6, were made out for convenience. Three curves are shown :—

(*a*) One showing the microhenries per turn for a square of side up to 300 cms.

(*b*) One showing the number of turns required to give 1,000 microhenries for squares of side up to 300 cms.

(*c*) One showing the area-turns of such coils.

In practice it is found that when coils are made from these curves, the inductance is usually less than that required, by about 12 per cent. This may be accounted for, in part, by the fact that it is necessary to space the turns somewhat to keep down the self capacity and thus the inductance is not really proportional to the square of the number of turns.

It is observed however that there is a great advantage in keeping the size of coils as large as possible as the area-turns increase with the size of the coil.

In order to design coils for a given wavelength, certain capacities have to be allowed for, the values varying from 0·2 jar for a wavelength of 400 metres to 0·6 jar for a wavelength of 4,000 metres.

It is worth noting that it is unwise to use twin flex for the leads from the coil to the condenser or receiver, because flex has appreciable self capacity.

For rectangular coils, approximate values can be obtained by using the above curves and using the side of the square which has the same area as the rectangle, always assuming, of course, that the rectangle is not too elongated. It is safe enough to use this device for rectangles whose long side is not more than four times the short side.

(5) It will now be shown how to calculate the number of turns on the main and auxiliary coils for any specific conditions.

The wavelength being given, the capacity to be allowed is chosen to be somewhere near its best value. From this, the total inductance can be calculated. Let it be L microhenries.

Let the length of the side of the equivalent square of the main coil be a cms. and that of the auxiliary coil b cms.

Let there be n_1 turns on the main coil

and n_2 ,, ,, auxiliary coil.

From Fig. 6 the inductance per turn for squares of sides a and b can be found. Let them be

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l_1 microhenries for the main coil, and,
l_2 „ „ auxiliary coil.

Suppose the ratio of the area-turns of the auxiliary to main coils is chosen to be k.

We have n_1a^2 = area-turns of main coil.
n_2b^2 = „ „ auxiliary coil

and $kn_1a^2 = n_2b^2$

giving $n_2 = \alpha\, n_1$

where $\alpha = k\left(\frac{a}{b}\right)^2$

The total inductance $L = n_1^2\, l_1 + n_2^2 l_2$ approximately

$$L = n_1^2\,(l_1 + \alpha^2\, l_2).$$

As L, l_1 and l_2 and α are known, n_1 can be calculated, and thus also n_2.

(6) There should be no mutual induction between the main and auxiliary coils, in order that the tuning may be unchanged on reversing the auxiliary coil.

8. TYPES OF COIL.

From the paragraph on design of coils it is shown that the points to pay attention to are :—

(*a*) The turns must be spaced so as to keep down the self capacity.

(*b*) The area-turns should be as large as possible for the wavelength to be used.

(*c*) The auxiliary and main coils should be as nearly perpendicular as possible, so that there is little or no mutual induction between them.

Three patterns of coil have been used :—

(1) *Box pattern.*—This type has the separate turns of a coil parallel to each other and in parallel planes, the planes being separated by $\frac{1}{8}$ inch to $\frac{1}{2}$ inch.

(2) *Pancake pattern* where each coil is wound with the turns all in the same plane.

(3) *Combination of box and pancake pattern.*—The idea underlying such a combination is to get the area-turns as large as possible for the given wavelength. This is equivalent to a number of parallel pancakes, and there is so much more space for winding

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than in either the box or pancake pattern alone, that it is possible to leave greater distances between the turns. This is of advantage in two ways, firstly the inductance for turns is smaller than if the turns were bunched closer together, and, secondly, the self capacity is reduced. In practice so far, only two parallel pancakes have been used.

In a subsequent paper some results will be given of the application of this method of direction finding to wireless navigation with especial regard to aircraft.

My best thanks are due to Major J. Erskine Murray, D.Sc., for the interest he has taken in the development of this method of wireless navigation, and for advice given on many occasions.

APPENDIX.

Note on the relation between the area-turns of a loop and the E.M.F. picked up from electromagnetic waves.

It has been assumed in the preceding paragraphs that the E.M.F. picked up is proportional to the area-turns of a loop. This law seems to hold when the number of turns in a loop is not too large, say up to forty turns. The following experiment proves this.

Referring to Fig. 3 we find that the curves cc_1 and dd_1 cut the axis of E.M.F. at the points S and T. Let the angle represented by SO and TO be $\theta°$.

Curve cc_1 is $Y_1 = a \cos\theta + b \sin\theta$

„ dd_1 is $Y_2 = a \cos\theta - b \sin\theta$

For Y_1 or $Y_2 = 0$ we have

$$\tan\theta = \pm \frac{a}{b}.$$

This ratio $\frac{a}{b}$ is the ratio of the maximum E.M.F.'s produced in the two coils.

Now k is the ratio of the area-turns of the auxiliary and main coils. Hence if

$$\tan\theta = \frac{1}{k}$$

the above assumption is correct.

This is found to be the case within 3 per cent. for coils with turns up to forty.

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The Effect of the Potential Drop along the Filament of a Valve on its Sensitiveness as a Detector.*

By E. GREEN, M.Sc.

This article is in the nature of a note on the papers by Dr. Eccles in the October—December issues of the RADIO REVIEW, and will follow his nomenclature as far as possible.

The effectiveness of a valve, as a rectifier (or detector) of small alternating currents is proportional to the value of $\frac{d^2I_a}{dE^2}$ for that point of its characteristic at which it is used. Here I_a is the plate current, and E the voltage at plate or grid, according as it is a diode or triode. *I.e.*, if ϵ is the maximum value of the small alternating voltage at plate or grid the rectified current is

$$\frac{1}{4} \cdot \frac{d^2I_a}{dE^2} \cdot \epsilon^2 \quad \ldots\ldots\ldots \quad (1)$$

Case of Diode.

We can apply this to the formulæ given by Dr. Eccles. First consider the case of a two electrode valve (a diode), consisting of a cylindrical anode, and an axial filament of length l. Let i_a = electron current drawn from unit length of filament by voltage e_a. I_a = total current from filament. Then we have

$$i_a = Ae_a^{\frac{3}{2}}$$

where A is a constant and i_a, e_a, refer to any particular corresponding parts of filament and anode. Now assume that the filament is all at one potential, so that i_a and e_a^2 are constant throughout its length.

$$\therefore \quad I_a = A \,.\, l \,.\, e_a^{\frac{3}{2}} \quad \ldots\ldots\ldots \quad (2)$$

and

$$\frac{d^2I_a}{de_a^2} = \frac{3}{4} \cdot \frac{A \,.\, l \,.}{e_a}$$

This has its maximum value when $e_a = 0$. In practice the alternating voltage $\epsilon \sin \omega t$ is of finite amplitude, and we cannot use $\frac{d^2I_a}{de_a^2}$ to find the rectified current when $e_a = 0$ but we can get an approximate value as follows. During half the cycle the current will be $Al(\epsilon \sin \omega t)^{\frac{3}{2}}$, and zero during the other half-cycle.

$$\therefore \text{ Rectified current } = \tfrac{1}{2} A \,.\, l \,.\, \epsilon^{\frac{3}{2}} \frac{1}{\pi} \int_0^{\pi} \sin^{\frac{3}{2}} \theta d\theta$$

and $\sin\theta \geqq \sin^{\frac{3}{2}}\theta \geqq \sin^2\theta$.

* Paper received January 1st, 1920.

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$$\therefore \frac{1}{\pi}\int_o^\pi \sin\theta d\theta > \frac{1}{\pi}\int_o^\pi \sin^{\frac{3}{2}}\theta d\theta > \frac{1}{\pi}\int_o^\pi \sin^2\theta d\theta.$$

$$\therefore \frac{1}{\pi}\int_o^\pi \sin^{\frac{3}{2}}\theta d\theta \text{ lies between } \frac{2}{\pi} \text{ and } \frac{1}{2}$$

$$\therefore \text{Rectified current lies between } \frac{1}{\pi}A.l.\epsilon^{\frac{3}{2}} \text{ and } \frac{1}{4}A.l.\epsilon^{\frac{3}{2}}.$$

We will take the smaller value.

If however the voltage drop along the filament is e_f, and the anode battery is connected to the negative end of the filament, the voltage between anode and filament at any point, distance x along the filament from the negative end, will be $e_a - e_f . x/l$.

$$\therefore i_a = A\left(e_a - e_f\frac{x}{l}\right)^{\frac{3}{2}}$$

and

$$I_a = \int_o^l A\left(e_a - e_f.\frac{x}{l}\right)^{\frac{3}{2}} dx \quad \ldots\ldots\ldots\ldots (3)$$

$$I_a = \frac{2}{5}.\frac{A.l}{e_f}\left\{e_a^{\frac{5}{2}} - (e_a - e_f)^{\frac{5}{2}}\right\} \quad \ldots\ldots\ldots (4)$$

$$\frac{d^2I_a}{de_a^2} = \frac{3}{2}.\frac{A.l}{e_f}\left\{e_a^{\frac{1}{2}} - (e_a - e_f)^{\frac{1}{2}}\right\} \quad \ldots\ldots\ldots (5)$$

When $e_a < e_f$ only that part of the filament for which $\left(e_a - e_f\frac{x}{l}\right)$ is positive will contribute to the electron current.

$$\therefore I_a = \frac{2}{5}.\frac{A.l.}{e_f}e_a^{\frac{5}{2}}, \quad \frac{d^2I_a}{de_a^2} = \frac{3}{2}.\frac{A.l.}{e_f}e_a^{\frac{1}{2}} \quad \ldots\ldots (6)$$

Hence $\frac{d^2I_a}{de_a^2}$ continually increases as e_a increases, as long as $e_a < e_f$.

When $e_a > e_f$, $\frac{d^2I_a}{de_a^2} = \frac{3}{2}.\frac{A.l.}{e_f}\left\{e_a^{\frac{1}{2}} - (e_a - e_f)^{\frac{1}{2}}\right\}$

This expression decreases as e_a increases, and therefore $\frac{d^2I_a}{de_a^2}$ has its biggest value when $e_a = e_f$. At that point

$$\frac{d^2I_a}{de_a^2} = \frac{3}{2}.\frac{A.l}{e_f}e_f^{\frac{1}{2}} = \frac{3}{2}.\frac{A.l}{e_f^{\frac{1}{2}}}$$

For the small alternating voltage $\epsilon \sin\omega t$ the rectified current will be

$$\frac{1}{4}.\frac{d^2I_a}{de_a^2}\epsilon^2 = \frac{3}{8}.\frac{A.l.}{e_f^{\frac{1}{2}}}\epsilon^2$$

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$$\therefore \frac{\text{Rectified current with no potential drop in filament}}{\text{Rectified current with potential drop in filament}} =$$

$$\frac{1}{4} A \,.\, l \,.\, \epsilon^{\frac{3}{2}} \times \frac{8}{3} \cdot \frac{e_f^{\frac{1}{2}}}{A \,.\, l \,.\, \epsilon^2} = \frac{2}{3}\sqrt{\frac{e_f}{\epsilon}} \quad . \quad (7)$$

And, as ϵ may be very small compared with ϵ_f, the value of this may be large.

Case of Triode.

Exactly analogous reasoning applies to the triode valve. If i_a = anode current per unit length of filament, e_a = anode voltage, e_g = grid voltage then neglecting potential drop along filament,

$$I_a = A \,.\, l \,.\, (e_a + g e_g)^{\frac{3}{2}} = A \,.\, l \,.\, e_l^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where A is a constant, and $e_l = (e_a + g e_g)$ and is the lumped voltage.

Taking potential drop along filament into account, the lumped voltage at any point is $(e_a + g \,.\, e_g) - (1 + g)\, e_f \frac{x}{l} = e_l - e_f' \frac{x}{l}$

where $e_f' = (1 + g)\, e_f$ $\qquad \therefore i_a = A\left(e_l - e_f' \frac{x}{l}\right)^{\frac{3}{2}}$

$$\therefore I_a = \int_0^l A\left(e_l - e_f' \frac{x}{l}\right)^{\frac{3}{2}} dx \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Comparing (8) and (9) with (2) and (3) we see that they are exactly similar in form with e_l in place of e_a and e_f' in place of e_f.

$\therefore$ we have a relation similar to (7):

$$\frac{\text{Rectified current with no potential drop in filament}}{\text{Rectified current with potential drop in filament}} =$$

$$\frac{2}{3}\sqrt{\frac{e_f'}{\epsilon_l}} = \frac{2}{3}\sqrt{\frac{(1+g)\, e_f}{g \,.\, \epsilon}} \quad . \quad (10)$$

Here $\epsilon_l = g.\epsilon$ is a small change in e_l where ϵ is the change in grid voltage.

Therefore in a triode for use as a rectifying detector, it would be a great advantage if the potential drop along the filament could be compensated for, or minimised, as much as possible. G. A. Bauvais has patented an arrangement whereby a current is passed through the grid wire, which is in the form of a spiral; and so the drop along the filament could be compensated for. Unfortunately the capacity of the grid battery would go far to neutralise the gain in sensitiveness. In some of the audions of the Western Electric Co., with plane grids and anodes, the filament is composed of several wires in parallel, and in this way e_f is reduced, and the detector sensitiveness increased. The writer is fully aware of the many other considerations which enter into the question when using a valve in an actual receiver, but still it seemed of some interest to show the effect of the potential drop along the filament in reducing the sensitiveness of the valve as a detector.

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The Coupling of Multiple-Stage Amplifiers.

By THE EDITOR.

Although thirteen years have elapsed since Dr. Lee de Forest invented the three-electrode thermionic valve, or audion, or triode, and described its use as a detector in precisely the same way as it is usually employed at the present time, it is only during the last six years that it has attracted the attention that it deserves. Few scientific discoveries have given a better return for the attention devoted to them. The possibilities of the audion and oscillion,—to use the names given to them by de Forest, than whom no one had a better right to christen them,—were just beginning to be appreciated when war broke out. In Germany it was regarded as too experimental and untried for it to be seriously considered during the early stages of the war, and little was done to develop it until it was found that, in the hands of the Allies, it had been developed into a reliable apparatus which was revolutionising the whole art of radio-communication. Not only in the United States, which as a neutral had every opportunity and inducement to develop the triode, but also in this country and in France a great number of physicists, radio engineers, and lamp makers were engaged in the development of the valve itself, its manufacture on a large scale, and the design and construction of the circuits and auxiliary apparatus for its various applications.

It will thus be seen that the triode has had the fortune—good or bad—to be developed almost entirely under war conditions and for the purposes of war. This fact has had a marked effect on the lines of development and has been the controlling factor in bringing triode apparatus to the form in which we have it at the present day. For the purposes of war apparatus must be, before all else, robust, simple in operation and as small, light, and portable as possible. The seven-valve amplifiers, consisting of say three high-frequency and three low-frequency amplifiers together with the detector, all mounted in a small box containing all the auxiliary apparatus, represented a marvellous achievement, which was not obtained without surmounting numerous difficulties.

Now that the war is over and this class of apparatus is being put to more peaceful uses, one cannot but ask whether, in many cases where portability and compactness are of secondary importance, better results could not be obtained by arranging the apparatus and dimensioning the parts differently. Very little has been published with reference to the relative merits and demerits of the various methods of coupling the successive triodes in a multiple-stage amplifier. In one method a non-inductive resistance of between 20,000 and 100,000 ohms is inserted in each anode circuit, one end being connected to the positive terminal of the anode battery, whilst the other end is connected to the anode and through a condenser to the grid of the succeeding triode. The high-frequency variations of the P.D. across the resistance are thus impressed on the grid. The condenser can be omitted

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if each triode has its own anode battery since the tapping can be made so that no steady P.D. is applied to the grid. At first sight one might think that such an arrangement would be independent of frequency, but such is not the case since the resistance is shunted by unavoidable capacities, the effect of which increases with the frequency. In the other and more commonly employed method a transformer is used and the grid circuit is thus electrically independent of the anode circuit except for the electromagnetic induction; no grid leaks are necessary and the grid voltage can be adjusted to any desired value. At one frequency the inductance of the primary of the transformer in combination with its self-capacity will form a resonant circuit, with a large current in the coil but a small current in the anode circuit. If the resistance R of the primary is small, its apparent impedance at this frequency will be ω^2L^2/R, which is very large if R is very small. Under these conditions the apparent impedance will vary greatly with the frequency. To remedy this the coil must be degraded; this can be done in several ways; for instance, by winding it with high resistance wire or by shunting it with a high resistance, or again, by providing it with an iron core in which losses occur, or even by providing a tertiary winding short circuited through a suitable resistance, or wound with high resistance wire and short circuited on itself.

Which is the preferable method and what are the main considerations that should guide one in designing the transformer in any one of these cases in order to obtain the best results with the minimum outlay? Should toroidal coils or astatic grouping of "D" or other shaped coils be adopted to reduce stray fields? What are the relative merits of various types of coils with respect to the effects of self-capacity? If tappings are brought out from large coils so that they may be used for short and medium wavelengths, are the results obtained inferior to those obtained with specially wound small coils? Iron-cored transformers have been proposed and used even for high-frequency amplification. In this case the laminations employed should not exceed about a twentieth of a millimetre in thickness. In any discussion of the merits and demerits of such transformers it must be borne in mind that with stations working at such wavelengths as 15 to 20 kilometres, the frequency is less than 20,000, which is approaching the audible limit. It is quite possible that for such low radio-frequencies iron-cored transformers could be employed with advantage. In all iron-cored transformers, whether for frequencies of 1,000 or 20,000, further problems arise, such as the effect of the fineness of lamination of the core, the quantity of iron which gives the best result, the relative advantages of open and closed magnetic circuits, the best ratio of turns for a given valve characteristic, and so on. These are some of the problems needing elucidation by systematic experimental investigation and it is hoped that these notes will lead to such research being undertaken, and also to the publication of results already obtained. Much work has undoubtedly been done already but in spite of the flood of thermionic literature which has been poured forth in every country, remarkably little has been published on the practical points mentioned above.

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Wireless Telephony on Aeroplanes.*

By Major C. E. PRINCE, O.B.E.

This paper gave a brief summary of the subject of wireless telephony as used on aircraft. Since the use of wireless telephony on aeroplanes came into being almost entirely during the war the treatment given necessarily largely dealt with the developments of the subject by the R.A.F.

Soon after the outbreak of war an experimental set was made up and tried out in the air, and at the first tests some approximation to intelligible speech was received. This, in the summer of 1915, is believed to be the very first occasion in the world when wireless speech was received from an aeroplane. In the early stages the difficulties of reception of speech in the air were so great that only transmission from the air to the ground was attempted, and the first practical set evolved was a transmitter capable of employing either speech, continuous waves, or interrupted continuous waves (subsequently called "tonic-train"). In this set an ordinary inductive reaction coupling was used between the anode and grid circuits of the oscillating valve. The anode circuit was tuned by a variable condenser and inductively coupled to the aerial circuit. The high tension voltage was 600, and was supplied from a dry battery of small cells weighing about 36 lbs. Some of the best ground microphones proved useless in the air and the choice finally rested on an old type Hunnings Cone. The above set weighed 10 lbs. without batteries. It was used on a trailing aerial 250 feet long and employed a wavelength of approximately 300 metres, which was not very far removed from the natural wavelength of the aerial.

This apparatus was exhibited at the meeting, as well as an interesting collection of other and later sets.

Reception on the ground was first carried out with a Marconi double magnification circuit in which a single soft valve was employed for both high and low frequency magnifications and a carborundum crystal was used for rectification. Reaction was used to the utmost, and great sensitiveness was obtained. The ordinary working limit of range from air to ground was about twenty miles for telephony, thirty to thirty-five for tonic-train, and about double this distance for pure continuous waves. Signalling from ground to air was carried out by telegraphy with a $\frac{1}{2}$ kw. spark set.

Later on a demand arose for communication between machines in the air, but for a long time there was still no demand for both-way working, and the machines were equipped either for transmission (for the leader to give orders), or for reception (for his formation to receive them). Dealing first with the transmitting apparatus an ordinary reaction or regenerative circuit provided the radio power, but the main electrical difficulty was the choice of the best method of applying the voice modulations. The earlier coupled system was ruled out on account of the complication of the coupling and tuning adjustments. The development of the "choke" or "constant-

* Abstract of paper read before the Institution of Electrical Engineers (Wireless Section), on February 18th, 1920.

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current" method of modulation control was traced in detail in the paper, leading up to the final simplification in which a common high tension battery was used for both the modulating and the power valve. The circuit arrangement finally adopted is indicated in Fig. 1. V_1 is the oscillation valve having its anode circuit closed through the aerial inductance L_2, and its grid coil L_1 inductively coupled to the anode circuit. V_2 is the modulation valve controlled by the microphone M. The choking inductance L_0 is included in the common output circuit of the high tension battery B_2. When variations take place at speech frequency in the controlling valve anode circuit, very large surges are set up in the anode circuit of the power valve which may approximate in magnitude to the original H.T. potential and thus modulate the output from nearly double its steady value to almost zero. This choke control proved pre-eminently suitable for air working and no other method of modulation survived in competition with it. The action of the choke coil was subsequently investigated in greater detail and it was found that for a sound frequency of 750 per second an inductance of not less than five henries was required. Resistance as such was always detrimental.

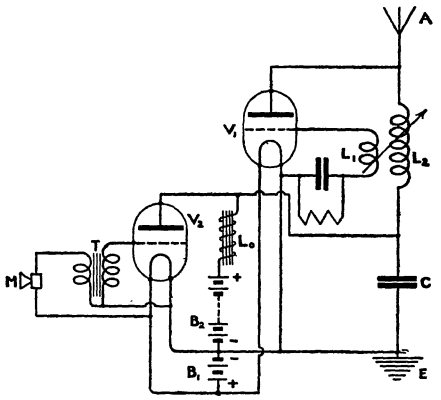

FIG. 1.

In the general layout of the set on the aeroplane things were so arranged that the apparatus proper could be mounted in any convenient position at a distance, while only a very small control unit for operating it was brought within reach of the user's hand. This simplification proved very essential for aircraft work and it is probable that much of the British lead was due to consistently designing to fulfil at all costs the needs of actual service conditions rather than to a laboratory standard. Considerable difficulties were experienced in the design of a suitable microphone set and best results were in the end obtained with a microphone which was devised to be almost insensitive to sounds of the intensity of the disturbing noises but responsive to the powerful concentrated sound waves of a voice impinging upon it from a very short distance. This instrument appeared curiously dead and ineffective on the ground, but nothing else was able to work so effectively in a noisy machine.

The difficulties in the design of a receiving set for use on aircraft need no emphasis when the general uproar of the engine and wind is remembered. It was only comparatively lately that high frequency magnification became sufficiently manageable for introduction into aircraft. The arrangement which survived consisted essentially of a detector valve with reaction and two note magnifications. The detector valve was energised from the aerial through a so-called aperiodic circuit which was really a circuit approxi-

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mately syntonised by its self-capacity. This arrangement was found to reduce magneto noises considerably. Reaction was controlled by varying the filament brightness, firstly because this involved only a small control unit near the user, and secondly because altering the reaction in this way caused less disturbance to the wavelength. The effect of this control was demonstrated at the meeting. The general layout of the receiving circuit is indicated in Fig. 2.

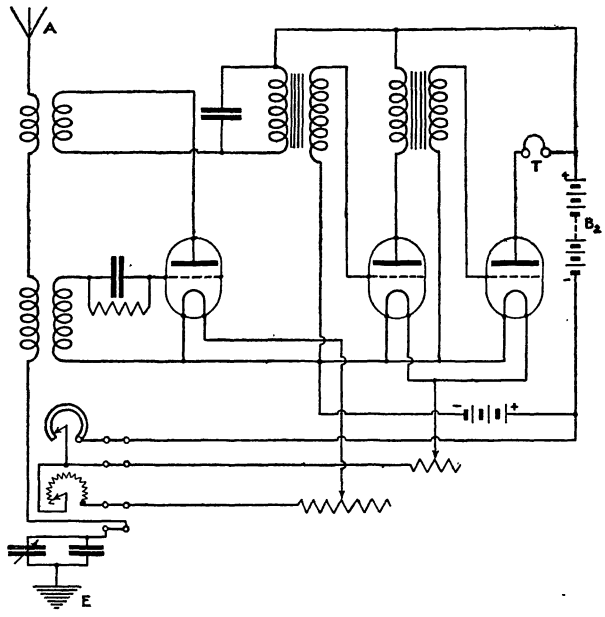

FIG. 2.

(*To be concluded.*)

Measurement of the Chief Parameters of Triode Valves.*

By Prof. W. H. ECCLES, D.Sc.

When a tube is about to be put into use we require to know one or two commonplace facts concerning it, such as the appropriate filament current and voltage which are easily found out or can be supplied by the maker. But there are other properties of the tube—such as the voltage ratio under conditions of normal use—which usually have to be specially measured and which are essential for the formation of an accurate forecast of the performance of the tube in particular applications. A large number of parameters have been suggested for expressing numerically the various properties of triodes, but not all of them are equally important nor are all of them independent. In this paper attention is devoted to parameters belonging purely to the tube. Mixed functions of the tube and its circuits can usually be deduced from the data of the circuits and of the true parameters of the tube itself.

At any given filament voltage or current the principal parameters of the triode are:—

(1) The coordinates of the mid-point of the straight part of the lumped characteristic.

* Abstract of paper read before the Physical Society of London on January 23rd, 1920.

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(2) The voltage factor g.
(3) The differential coefficient di_a/de_a or h_a.
(4) The differential coefficient di_a/de_g or h_g.

The last-named parameter is not independent of the preceding two, since $h_g = gh_a$.

From a knowledge of these magnitudes the main aspects of the behaviour of the triode when connected to any kind of apparatus can be calculated. All of them can be deduced from the characteristic curves of the tube, but as the drawing of a number of complete curves is laborious, various methods of directly determining the most important parameters are indicated in the paper.

Direct-current methods of carrying out these measurements have certain advantages over methods using rapidly alternating currents and a telephone receiver, although they are not so quick and convenient. The use of alternating current frequently gives rise to accidental electric and magnetic coupling between portions of the same and other circuits which interfere with the accuracy of the measurements.

The coordinates of the mid-point of the straight part of the lumped characteristic may be determined by connecting a shunted galvanometer of low resistance into the anode circuit of the tube and increasing the anode voltage until the current as indicated by the galvanometer ceases to increase. Resistance may then be added to the anode circuit until the galvanometer reading is reduced to one-half of the saturation value. Calling this current of half the saturation value, i_1, the anode circuit voltage E, and the resistance added to the circuit R, the required coordinates are i_1 and $e_1 = E - Ri_1$. It should be noted that the value of e_1 obtained in this manner is a lumped voltage and that it may be made up by any anode voltage and grid voltage that satisfy the equation $e_a + ge_g = e_1$, where e_a is the anode voltage and e_g the grid voltage and g the voltage factor as defined above.

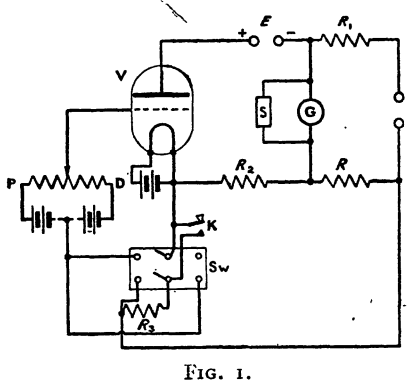

FIG. 1.

Special circuit arrangements are given in the paper for determining the values of h_a, h_g and g by direct-current methods. These arrangements are of a very similar nature to those described by S. Ballantyne,* the chief difference being that direct current is used instead of the varying currents as described by Ballantyne.

The three methods of measurement described may also be carried out by the aid of a single piece of apparatus connected as indicated in Fig. 1. A special feature of this arrangement is the six-point switch S_w which in the

* "The Operational Characteristics of Thermionic Amplifiers," by S. Ballantyne, *Proceedings of the Institute of Radio Engineers*, 7, pp. 129—186, April, 1919.

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apparatus described was made with mercury cups in order to ensure good contacts. With the switch in the left-hand position the connections are as required for determining h_a, balance of the galvanometer being sought for in both the up and down positions of the key K, adjustment being made by varying R_1 and R while R_2 is given any desired fixed value. The value of h_a is then given by $h_a = R/R_1R_2$. When the switch is in the right-hand position h_g may be determined by balancing the galvanometer for both the up and down position of the key K, by adjustment of R_1 and R_3. R should be given some definite small value and R_2 should be made zero. The value of h_g is then given by $h_g = \frac{1}{R_1 + R_3 + (R_1R_3/R)}$. To determine g, R_3 should be made zero, the key K left up and the galvanometer balanced for the switch S_w in either the right or left-hand position by adjustment of the values of R_2 and R. The value of g is then given by the ratio of R_2 to R.

In the discussion Professor C. L. FORTESCUE said that the methods described should give great accuracy, but as they would be sensitive to very small variations of the filament current, he did not think that the author had sufficiently emphasised the importance of maintaining the filament current at a predetermined value. He also thought that for practical purposes one would frequently want to test the complete characteristic of the valve rather than determine these isolated quantities.

Professor G. W. O. HOWE said that the suggestion of a single "lumped" characteristic was attractive, but that in practical work it was very desirable to have the various characteristics for each grid voltage. He also, together with Professor O. W. RICHARDSON, criticised certain statements made in the paper as to the application of Ohm's Law to valve characteristics.

Mr. F. E. SMITH considered that the methods described by Dr. Eccles should be particularly valuable where large numbers of valves had to be tested.

On some Experiments in which two neighbouring maintained Oscillatory Circuits affect a Resonating Circuit.*

By J. H. VINCENT, M.A., D.Sc.

In the experiments described in this paper two oscillating valve circuits were set up on neighbouring benches and a wavemeter circuit arranged to be loosely coupled to each of them. When the two oscillating circuits are tuned so as to be in absolute unison, the resultant current in the resonating wavemeter circuit will be a function of the phase difference between the oscillating circuits, and on this view will be a mere matter of chance. If the induced e.m.f.'s are equal in amplitude and exactly opposite in phase, no resultant current will flow. In these experiments the resonating circuit had its condenser shunted with a carborundum crystal in contact with brass, in series with a microammeter and a telephone. No direct measurements of the wavemeter current were made but the readings of the galvanometer in series with the crystal were recorded throughout.

As no method was available for measuring the alternating currents in the

* Abstract of paper read before the Physical Society of London on January 23rd, 1920.

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oscillators directly, the coil in each oscillating circuit was wound with a few turns of insulated wire which was connected in series with a microammeter and crystal detector.

The axes of the main oscillating coils were placed parallel, and the axis of the resonating circuit coil was parallel to the line joining the ends of these main coils, and a few feet away. Thus if the two maintained circuits were in phase the induced e.m.f.'s in the resonating circuit would be conspiring together. The frequencies used were of the order of 100,000, but other frequencies gave similar effects.

The resonating circuit was carefully tuned to the circuit on "Bench 1," and the capacity of "Bench 2" circuit slowly increased through the resonance point. The curve of current indicated by the resonating circuit galvanometer is indicated in Fig. 1, which also shows the currents induced by either

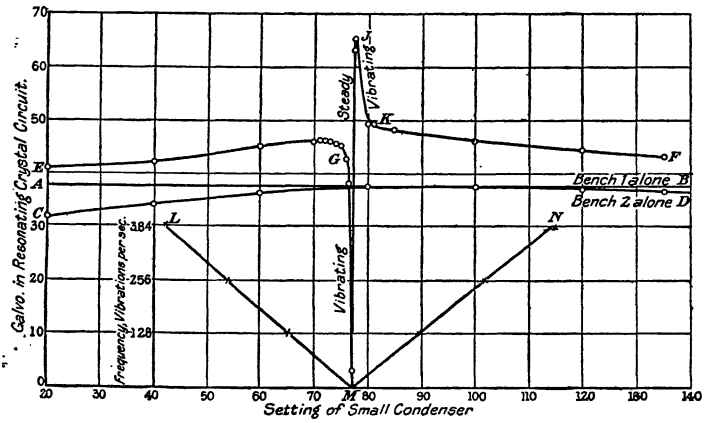

FIG. 1.

oscillating circuit when operating alone. At the same time the pitch of the note in the telephones fell uniformly with the increase of the Bench 2 capacity, as indicated by the line LM in the figure. At the point G the wavemeter galvanometer showed signs of vibrating. This vibration decreased in frequency till M was reached when the two oscillating circuits were in exactly opposite phase, and the resultant current in the wavemeter was zero. On further increasing the capacity the two circuits were gradually brought into phase, and at J this was complete. The change from M to J was brought about by an increase of capacity of a twentieth of a centimetre in a total capacity of 450 cm. During this change from M to J the galvanometer needle did not vibrate.

It was found that when the amplitude of the oscillations in either circuit was sufficiently reduced, the minimum (opposition of phase) occurred before or after the maximum according as Bench 1 or Bench 2 circuit was weakened.

When coupling was introduced between the maintained circuits, the shape of the curves was somewhat altered and the peak became much more rounded,

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while in particular the dead space over which the capacity could be adjusted without change in frequency was very much increased.

These experiments provide a means of observing very small changes of frequency by means of a galvanometer instead of by the usual beat method.

The paper was followed by a short discussion in which Dr. W. H. ECCLES, Professor O. W. RICHARDSON, and Mr. C. E. WEBB took part, and emphasised the extreme sensitiveness of the method. Some such arrangement will probably become a standard form of wavemeter in the future.

Dr. VINCENT in reply stated that he had not been able to add any theory to the paper, but that the results were put forward purely as an experimental research.

On the Measurement of Amplification given by Triode Amplifiers at Audible and at Radio Frequencies.*

By F. E. SMITH, F.R.S., and the late H. C. NAPIER, M.A.

The quantitative measurement of the amplifying powers of valves is a matter of considerable interest. In the first tests described a four-valve low-frequency amplifier was used, having iron-cored transformers between the successive valves. The first valve of the set was used as a standard of comparison, and the amplification of the remaining three valves was compared with it. A buzzer was first used as a source of sound, but it was subsequently replaced by a triode valve set generating oscillations of an audible frequency. To this valve set an aperiodic circuit was coupled containing the primary winding of a special air-core transformer, having two secondaries crossed at right-angles and capable of rotating together about a vertical axis passing through the plane of the outer primary winding. The mutual inductance between the primary and either secondary was measured for various angular positions by means of a Campbell inductometer. A special multi-contact switch was used to connect either secondary to the grid circuit of the first valve, and simultaneously to change over the telephones from the anode of the first valve to the anode circuit of the last. The position of the two secondaries was then adjusted until equality of sound was obtained in each case. The ratio of the mutual inductances to the two secondaries is then a measure of the voltage amplification of the three valves. For large amplifications (over twenty) the switch is arranged to vary the magnitude of the primary current from the oscillating valve simultaneously with the change-over from one valve to the amplifier. The ratio of mutual inductances must then be multiplied by the ratio of currents to give the amplification. Comparisons were made with a modified shunted telephone method, in which the sound in the telephone using the four valves was shunted down until it was of the same intensity as the sound obtained with one valve. The results obtained with the two methods were similar, but the shunt method tended to give lower values for the larger amplifications. The conditions of operation of the valves are not however the same.

For measurements on a radio-frequency amplifier the above method was found to be scarcely suitable owing to stray couplings between the cir-

* Abstract of paper read before the Physical Society of London on January 23rd, 1920.

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cuits. For the high-frequency tests a single-valve oscillator was used and connected to a rotating contact maker that intermittently joined a second inductance in parallel with the main oscillation circuit inductance and thus threw the valve out of tune. This gave better results than interrupting the anode circuit. "Chopped" high-frequency circuit was thus obtained with a note frequency of about 800 per second. The essence of the method used for measuring the amplification lies in comparing the intensity of the note obtained with a single receiving valve plus rectifier, with the intensity obtained from two or more valves plus the same rectifier. The intensities of signals in each case were adjusted by varying the oscillatory current at the source and reading the two values on a thermoammeter. The variations in the strength of the oscillatory current were brought about by varying the grid potential by means of a switch. The grid potentiometer was adjusted until equal sounds were heard in the two positions of the switch, after which the two oscillatory currents could be read off at leisure.

A Method of Measuring the Amplification of a Radio-Frequency Amplifier.*

By F. W. JORDAN, B.Sc.

The particular amplifier examined by this method was the French radio-frequency amplifier, type L.1, having six valves — three for radio-frequency amplification, the fourth for rectification, and the fifth and sixth for audio-frequency amplification. As source of radio-frequency waves a single oscillating valve was used with the plate voltage supplied from the filament battery. An audio-frequency voltage derived from a "tuning-fork alternator" was also superimposed upon the plate circuit and the magnitudes of the voltages adjusted until the radio-frequency oscillations were extinguished once in each cycle of the applied audio-frequency. A variable coupling was then arranged between the valve oscillator and the amplifier, special care being taken that all connecting leads, etc., were effectively shielded in earthed tubes. The amplifier was about 18 feet away from the oscillator and in another room.

The procedure which was adopted in making a comparison of the different groups of valves was to vary the input energy to the receiving circuit of the amplifier by means of the above-mentioned variable coupling, until the intensity of the note in the telephones was equal to a comparison standard.

A comparison standard of sound of the same frequency as the note in the telephones was obtained by inserting a dial potentiometer in the plate circuit of the "fork alternator." This potentiometer was brought close up to the receiving circuit, the leads being encased in earthed lead tubing. A switch was provided for quickly changing over the telephones from the amplifier to the potentiometer for the comparison sound, and *vice versâ*.

A simple method was also described by means of which the scale of the variable coupling used between the amplifier and the oscillator could be

* Abstract of paper read before the Physical Society of London, January 23rd, 1920.

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calibrated. For this purpose a second secondary coil having half the number of turns of the proper secondary was mounted on the opposite side of the primary. These two coils were connected in series in opposition, and by adjusting their relative positions the distance at which the mutual inductance was halved was readily determined. A binary scale for the mutual inductance was thus very easily obtained.

The object of the experiments was not to attain a high order of accuracy, but to devise some trustworthy method of comparing the performance of the separate valves of an amplifier and of different amplifiers.

Direction and Position Finding.

By Captain H. J. ROUND.

(*Concluded from p. 237.*)

Notes on Night Effects.—Large swing readings are better than minimum readings. To obtain readings of the actual minima at night is also very difficult. With signals from a spark station when there is no definite zero, peculiar changes of note are often heard. A very distinct difference of note will often be obtained in the two positions on opposite sides of the minimum. In England and France errors of swing readings on spark stations are present up to about 7° at night, and seldom more, but at Salonica the apparent position of Sofia would sometimes shift through as much as 90°. Nearly always, but not invariably, night variations are accompanied by bad minima.

Continuous waves give much greater variation than spark waves and with them directions are often seriously wrong even when the minima are extremely sharp. The apparent direction is apparently a function of the wavelength. Horsea arc station sent Press messages with a spacing and marking wave. These two waves sometimes gave directions differing by 30°, although each wave gave a perfectly sharp minimum. This point may be intimately connected with the results obtained at San Francisco by Dr. Lee de Forest some years ago on interference effects.

There is no strong evidence to show that the night variations on long waves are greater than those on short.

In England variations from east to west are certainly greater than those from north to south, but as far as is known this result does not agree with results from the East and from America.

When signals come oversea from moderate distances and practically no land intervenes the results are then the most reliable.

The minimum distance at which night effects have been noticed in England or France is about fifteen miles.

Captain Tremellen noticed that when two transmitting stations with differently shaped aerials were side by side, the apparent directions obtained at night by a Bellini-Tosi receiving station were different.

Mountainous country between the stations seems to give the worst night effects.

Daylight Errors.—The daylight errors were seldom as large as the possible

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errors of the instruments. Stations on the edges of high cliffs, near high trees, or near a wood gave trouble.

Refraction over a coast-line also undoubtedly exists. The presence of hills on one side of the station even some miles away, tends to give bad daylight minima in that direction.

Further Improvements.—After 1915, aperiodic aerials were used, but this brought about additional error due to an exaggerated form of "vertical." This error was overcome by earthing the mid-points of the two direction-finder coils.

With the introduction of an aperiodic direction-finder it was found that direct reception on the coils of the receiver was causing slight errors. In the case of the search coil of the radiogoniometer, this error can be avoided by placing the radiogoniometer in the correct position on the table. In the case of all other coils it may be avoided by a metal shield. A metal shield inserted between the windings of the transformer coupling the radiogoniometer to the amplifier is effective except on waves under 400 metres, when in addition it is necessary to earth the centre point of the aerials. Direction-finders for 200 metres constructed with either eleven or even twenty-two valves in cascade enabled a watch to be kept on buzzer intercommunicating sets.

Maps.—In certain side lines direction finding required investigation work, more particularly in map projection. At first Mercator charts were used, but these were very troublesome. A great improvement was obtained when charts on the gnomonic projections were used.

Atmospherics.—An interesting side line of D.F. work was its bearing on X-stopping. At night time, particularly in spring and autumn, X's exhibited very frequently (in fact most of the time in England) a sharp direction which centred a little round the position of 165° east of north. It was suggested that this direction was curiously near the magnetic meridian and perhaps it may be possible to determine if freak signals and consequently X's have more tendency to be reflected along the earth's magnetic field by the Heaviside layer.

Frame Aerials.—If the frame required is large and it is proposed to use a coupled circuit to the detector, a one-turn frame is as good as anything else, provided the resistance losses in the wire and in the condenser are kept small. If direct reception is required on a frame, then with all modern amplifiers with a non-conducting grid circuit, the frame should have the maximum number of turns and the smallest condenser which the receiver will take.

The conclusion of the paper briefly referred to some experiments carried out with several ships of H.M. Navy and in some Handley-Page aeroplanes. Appendix I. of the paper considered mathematically the action of the waves on two-spaced aerials. Appendix II. gave an elementary mathematical consideration of the valve as an amplifier, and Appendix III. a few notes on the use of a valve for limiting the strengths of loud signals. The last concluded with a reference to an arrangement due to W. T. Ditcham which consisted in dulling down the filament of a valve, and instead of working at

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the rectifying point, having a grid potentiometer which controlled the characteristic from end to end. It was found that with a particular filament brilliancy, at one point of the potentiometer signals from one station would vanish, and at another point a different station would vanish. An extremely fine adjustment was necessary since small changes of the order of $\frac{1}{100}$ of a volt are sufficient to cut out one station or another.

DISCUSSION.

Admiral Sir HENRY JACKSON referred to the great value that the direction-finding stations had been to the Navy and stated that the observed small movement of the German ships as indicated by the direction-finding readings enabled our fleet to intercept them at the Battle of Jutland.

Dr. J. ERSKINE-MURRAY referred to the difficulties experienced with the Bellini-Tosi system which had led to the development of the R.A.F. frame aerial receiver for aircraft. The latter arrangement usually gave an accuracy of $1\frac{3}{4}°$ in the air and about $\frac{1}{4}°$ on the ground.

Prof. G. W. O. HOWE thought that these experiments were likely to throw considerable light upon theories of transmission, and also inquired as to the relative accuracy of the readings in Fig. 1. If these are correct the movements of the ionised layers must be extremely rapid.

Colonel WACE stated that the disadvantages of wireless for linking up D.F. stations were entirely due to the use of plain language in such communications instead of code.

Mr. J. E. TAYLOR in referring to the coupling often obtained between the two Bellini-Tosi aerials stated that this difficulty was not obtained with frame aerials. He also thought that the question of the reflection of the waves from ionised layers in the atmosphere was not yet proved, and suggested that there ought also to be reflections from irregularities in the surface of the ground.

Major PRINCE in referring to the R.A.F. direction-finding system thought that this arrangement was really a minimum method and not a maximum one, and that it could be looked upon as a signal of sensibly constant strength from the main coil upon which was impressed the signal from the auxiliary coil at its minimum position.

Mr. St. V. PLETTS in referring to the question of map projections thought that gnomonic plotting was only best when there were more than two stations to be considered. It gives true directions and also gives true distances by a simple graphical method as has been shown by Dr. Eccles. Unfortunately it gives considerable distortion if a long narrow strip of country is considered. He thought it better to magnify the scale of the map in one direction. This could be done without destroying the advantages of the projection.

Capt. HUGHES referred to the difficulties experienced in France through the errors of direction finding. He thought it had been fairly well established that the apparent direction of stations to the east of the sunset line tended to swing to the southward. It was also probable that at sunrise there would be an opposite effect. There was a certain regularity in the sunset effects, but their magnitude varied from day to day. The sunset variations were less on a frame aerial than on a Bellini-Tosi arrangement, and there frequently appeared to be a sharp minimum on the frame when the minima were flat on the Bellini-Tosi. In connection with reception from Horsea Station the minima appeared to be flatter on some harmonics than on the fundamental. In the case of D.F. stations on hills, the position on the hill was very important.

Lieut.-Commander DITCHAM thought that the perfection of direction-finding arrangements had been one of the great technical successes of the war. He stated that in his experience the night effects were more pronounced with continuous waves than with signals from spark transmitters.

Capt. J. ROBINSON considered that this paper was one of the most complete that had been published on direction-finding work, but he also thought that the statements made relative to the crossed coil arrangements were scarcely fair to the R.A.F. With reference to the night effect errors he had never observed as much as 30° variation when working in these latitudes. He thought that some complications might arise with C.W. reception owing to the heterodyne radiation, and referred to Armstrong's paper read before the Institute of Radio Engineers.

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When using a radiogoniometer the coupling between the search coil and the fixed aerial coils would depend upon the position of the search coil and therefore when rotating the search coil the heterodyne radiation varied, and so the "heterodyne" amplification would vary. Consequently the position of the minimum would not be quite accurate. With any direct coupled system such errors are not introduced, and this may be the reason why the R.A.F. crossed coil arrangement gives more accurate results. He thought that small frame coils were best in order to reduce the effect of night variations. With reference to the "radiophares" referred to in the paper, their use might lead to considerable simplifications in direction-finding work on aeroplanes.

Mr. GOSSLING emphasised the value of this research work which had been carried out through all stages of the war and covered a wide range of subjects.

Mr. SHAUGHNESSY referred to experiments he had carried out, and in particular to the use of a small inductive "coupling-balancer" connected in circuit with the two aerials so that any external coupling between the aerials could be balanced out. He thought that the errors arising through such coupling between the aerials would not exceed $\frac{1}{2}°$.

Dr. ECCLES thought that the paper was very useful, particularly from a scientific point of view, and that it confirmed the work of French engineers on the same subject. He thought that as regards night and day work there was an additional component of wave energy arriving at the receiver at night as compared with that received during the day. This extra component arises through reflection by the ionised layers which are regular at night but not during the day. It would frequently be out of phase with the direct component of the wave and hence would give rise to the badly defined minima.

Capt. ROUND briefly referred to the possible errors arising through heterodyne reception mentioned by Capt. Robinson. The fact that these errors occurred only at night time scarcely supported the view put forward. He also pointed out that the total mutual inductance between the search coil and the two fixed aerial coils remains practically constant throughout the revolution of the coil, and that, therefore, the intensity of the heterodyne amplification would not appreciably vary when moving the search coil.

A Portable Set, and some Properties of C.W. Circuits.*

By R. C. CLINKER.

The apparatus shown at this meeting consisted of a complete unit comprising frame aerial and two-valve receiver mounted inside a single containing case with carrying handle. The box measures approximately 14 ins. × 12 ins. × 5 ins., and weighs about 20 lbs. complete with accumulators. The frame aerial is wound round the box inside, and a smaller coupling coil is hinged in front. This latter coil is joined in the anode circuit of the first valve and provides an adjustable regenerative coupling. The first valve acts as a detector (and self heterodyne when required) while the second is a low frequency amplifier. The filament accumulators (4 volts) and high tension battery of dry cells (43 volts) are also included in the case. These are mounted inside the frame coil, and although they increase the decrement losses when in that position, this increased loss is not found to be serious. Illustrations of the set will appear in the Society's official report of the meeting.† The lid of the case, when the set is in use, may be detached and thus forms a base with pivot round which the frame may be turned for determining approximate directions of incoming signals.

* Abstract of paper delivered before the Wireless Society of London on January 29th, 1920.

† *The Wireless World*, March issue.

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Demonstrations of the formation of beats between two such sets placed about twelve feet apart were made, and also of the reaction of a tuned secondary coil coupled to one of the sets. The " double click " method of indicating when this external coil was in resonance with the oscillator was also shown, and the lecturer pointed out that the two frequencies at which these " clicks " occur are the two frequencies that normally occur when two tuned circuits are coupled together.

The effect of insulating the grid of a valve and the discharging effect due to the presence of radium were also demonstrated.

Prof. G. W. O. HOWE, in discussing the paper, indicated a simple method by which the presence of the two coupling frequencies could be demonstrated by considering the magnetic field linking the two coupled coils.

Mr. J. SCOTT-TAGGART briefly described the measurement and comparison of capacities using the well-known heterodyne method.

Admiral Sir HENRY JACKSON stated that he had experienced difficulties in reception on a frame coil inside a building containing a number of iron pipes, and pointed out that the experiments with the coil coupled to the oscillator formed a simple demonstration of such effects being caused by the proximity of the metal to the frame coil.

Mr. P. R. COURSEY described an alternative to the double click method using a thermo-galvanometer in the oscillating circuit and noting the drop in current when the coupled coil was brought into tune; and Mr. BROADWOOD referred to a similar method using a galvanometer in the plate circuit of the valve instead of a telephone.

Mr. R. C. CLINKER replied briefly to the points mentioned, and also demonstrated how the two oscillating circuits pulled into phase when they were coupled sufficiently closely, in a similar manner to two alternators connected in parallel.

A Wireless Calling Up System for use on Ships.

On Thursday, January 15th, 1920, a demonstration of some new instruments designed for the above purpose was given by Marconi's Wireless Telegraph Co., Ltd., at their works at Chelmsford.

The transmitter is designed to radiate a series of dots at a frequency of 180 per minute on the standard 600-metre ship's wave and the receiver is designed to respond to a series of dots of this frequency only.

The transmitter consists of a small oscillating flywheel which is controlled by a spiral spring and adjusted to swing at the desired rate. At each swing a contact is closed which operates a relay signalling key in the transmitting circuits. The wheel is set in oscillation by pressing a small key which passes a momentary current through the magnets which maintain its vibration. At the receiver a three-valve amplifier is used in conjunction with an oscillating relay of a similar type to the oscillating system used at the transmitter. The receiving relay is tuned to respond to 180 impulses per minute. The small balance-wheel of the receiving relay is set in motion by the amplified received currents which are passed through two electromagnets, and on the receipt of a sustained series of dots at the proper frequency the amplitude of the oscillations is built up until a contact is closed and the call bell operated.

The device appears to be remarkably immune from disturbance by jamming from ordinary wireless signals and to be quite reliable in operation.

Its normal working range in the present form is about eighty miles.

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Review of Radio Literature.

1. Abstracts of Articles and Patents.

212. THE USE OF AMPLIFIERS FOR THE MEASUREMENT OF SMALL DIFFERENCES OF POTENTIAL. R. Depriester. (*Revue Générale de l'Électricité*, 6, pp. 619—620, November, 1919.)

Blondel has pointed out that the arrangements of amplifiers described by him* are not the only possible ones. This article describes another—indicated in Fig. 1.

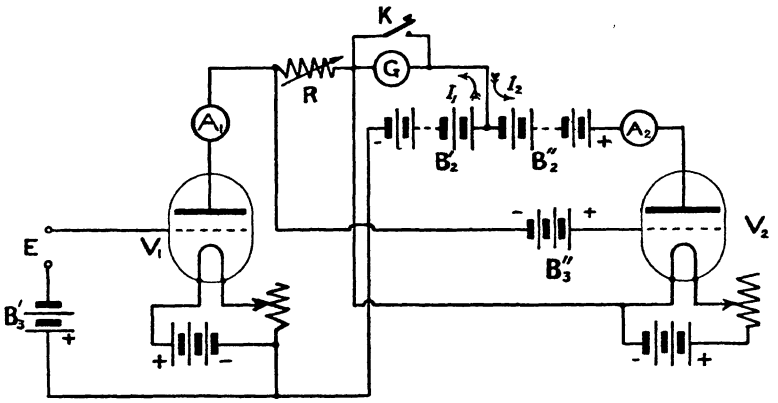

FIG. 1.

The two valves V_1 and V_2 are joined in cascade as shown, the grid of V_2 being supplied from the p.d. across the resistance R in the plate circuit of V_1. The small p.d. to be measured is applied at E. The plate currents of the two valves flow through G in opposition, and by proper adjustment this galvanometer can be brought to zero for the normal position. The valve filament currents and a part of R are adjustable for this purpose. The short-circuiting key K is for use when making preliminary adjustments of the equality of the plate currents using the milliammeters A_1 and A_2 as indicators. Greater sensitiveness may be obtained by the use of a preliminary amplifier.

213. HIGH-FREQUENCY AMMETERS. H. A. Ewen. (*British Patent* 132567, July, 1918. Patent accepted, September 19th, 1919.)

An inductive coupling between the hot wire ammeter and the aerial circuit

* RADIO REVIEW Abstract No. 237.

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is described for the purpose of measuring large high frequency currents. The calibration of the instrument may be varied by altering the coupling between the instrument circuit and the aerial circuit or by varying the resistance or inductance of either of the windings.

214. THE L.C. TABLE AND HOW TO USE IT. (*Everyday Engineering Magazine*, 8, p. 106, November, 1919.)

A table is given from which the product L.C. (inductance in cms. × capacity in mfds.) can be read off corresponding to any given wavelength.

215. THE OPERATION OF THE A.C. QUENCHED SPARK TRANSMITTER. K. Schmidt. (*Elektrotechnische Zeitschrift*, 40, pp. 562—564, November, 1919.)

A discussion of the conditions for obtaining a good musical note, viz: good quenching, exact resonance, and proper coupling. The wave form of the alternator may vary with the excitation, but at resonance the fundamental will greatly predominate. The purity of the tone is independent of the wave form, although it influences its character. Reproductions are given of cathode ray oscillograms showing the voltage and current curves with both one and two sparks per cycle. To obtain a very low number of sparks per second, that is, one spark for several cycles, it is advantageous to connect a choke coil in parallel with the alternator, thus making the total inductance of the circuit less dependent on variations in the alternator.

The protection of the alternator from high frequency surges by means of earthing condensers is discussed. Reference is made to Figs. 8 and 9, which, however, are missing.

216. TRANSATLANTIC RADIO COMMUNICATION. E. F. W. Alexanderson. (*Proceedings of the American Institute of Electrical Engineers*, 38, pp. 1077—1093, October, 1919; *Telegraph and Telephone Age*, 37, pp. 506—509, October, 1919, Abstract.)

Abstract of paper presented at a joint meeting of the American I.E.E. and the Institute of Radio Engineers. The author discusses the capabilities of large radio stations for handling the world's long-distance telegraph traffic. It is shown that, under present arrangements, the number of such world stations is limited to twelve, even when the wavelength range is extended down to 10,000 metres and up to 20,000 metres.

The tendency of present-day developments points to the following means for expansion of radio traffic :—

(1) Increase in speed of transmission.
(2) Improved selectivity based on the direction of the wave.
(3) Improved selectivity, making possible closer spacing of wavelengths.

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As to (1) and (3) it is pointed out that speeds up to 100 words per minute are now practicable, and that these speeds are not incompatible with increased selectivity to work with a 1 per cent. difference in wave length between stations. As to (2) the achievements of the author's "Barrage" receiver are discussed,* as well as the arrangement of multiple antennæ at the New Brunswick, N.J., station. This consists of six independent radiating antennæ, each with separate tuning inductances. By this means the total resistance of the complete aerial has been reduced from 3·8 ohms to 0·5 ohm at 13,600 metres, and the radiation efficiency raised from about 2·6 per cent. to 14 per cent. At 8,000 metres, the total resistance of the multiple aerial is 0·6 ohm and its radiation efficiency 30 per cent. The radiation from each component of the multiple aerial may be in phase, or by regulating the phase displacement, definite directive radiation can be

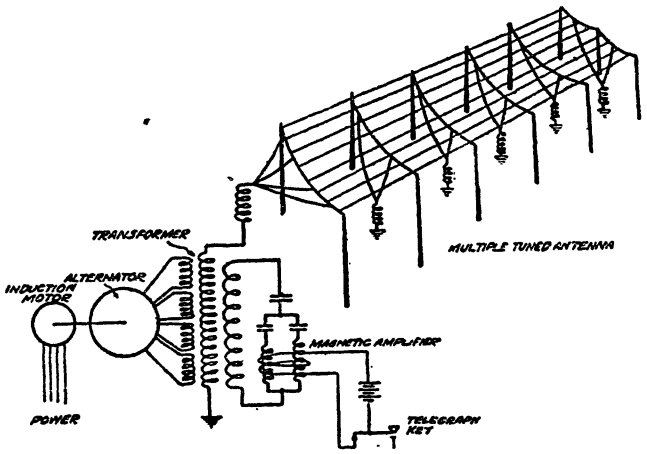

FIG. 2.

secured by utilising the interference effects between the separate radiated waves. [See, also, RADIO REVIEW Abstract No. 198.]

The arrangement of the multiple antenna is indicated in Fig. 2. It may be considered as an aggregate of several antennæ of the ordinary vertical type, each having its own tuning coil. The aerial at New Brunswick is therefore equivalent to six independent radiators placed 1,000 feet apart. The current in each ground lead is about 100 amperes, and the total power is then about 100 kw. The upper horizontal portion of the complete antenna acts as a transmission line between the separate aerial units. The tuning coil to which the alternator is connected raises the potential to 60,000 volts, and each of the oscillating circuits formed by the ground connections draws energy from this transmission line at that voltage.

* See RADIO REVIEW Abstract No. 75.

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217. IMPROVEMENTS IN ARC OSCILLATION GENERATORS. C. Lorenz. (*British Patent* 132799, June, 1918, not yet accepted but open to inspection.)

Irregularities in the production of electric oscillations by means of an arc are prevented by the use of a large inductance in the high frequency circuit. The aerial circuit may be closely coupled with this large inductance in the primary oscillation circuit or may be directly coupled to it. One such arrangement is indicated in Fig. 3. In this diagram inductances L_1 L_2 are coupled to present a large impedence to the currents flowing round the circuit S C_1 L_2 L_1 but to offer a low impedence to the aerial earth currents flowing through the two coils in parallel.

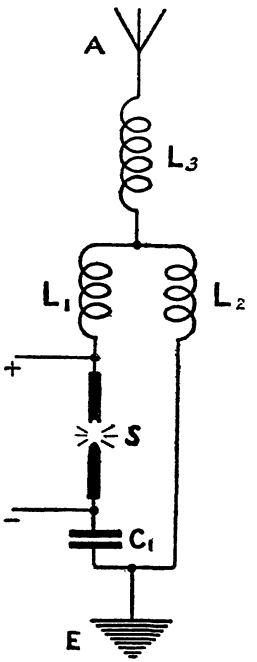

FIG. 3.

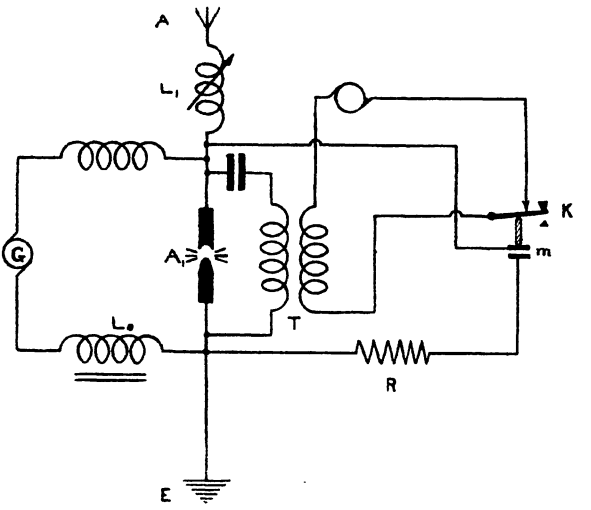

FIG. 4.

218. IMPROVEMENTS IN RADIOTELEGRAPHIC TRANSMISSION SYSTEMS. A. Taylor. (*British Patent* 133901, April, 1919. Patent accepted, October 23rd, 1919.)

For the transmission of Morse signals with an arc oscillation generator, signals are sent by interrupting the arc while maintaining the load on the supply circuit substantially constant. One arrangement is indicated in Fig. 4. The arc A_1 is shunted by the resistance R through the main contacts m of the key K so that when the key is operated the arc is extinguished. On releasing the key the momentary interruption of current through the choke coil L_0 induces a large voltage at the terminals of the arc and this brings

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about its re-ignition. In an alternative arrangement the key K when released may also close the circuit of a small auxiliary transformer, T, to induce a high voltage across the arc terminals to effect the re-ignition. The main contacts m of the key K are provided with a powerful magnetic blow-out. In a further modification described in the patent the action of the key serves to bring an auxiliary electrode into contact with one of the arc electrodes, thus shunting the arc through a resistance and causing its extinction. On releasing the key an arc is first formed between the main and auxiliary electrodes and this serves to re-ignite the main arc.*

219. A METHOD OF USING TWO TRIODE VALVES IN PARALLEL FOR GENERATING OSCILLATIONS. W. H. Eccles and F. W. Jordan. (*Electrician*, 83, p. 299, September, 1919. *Electrical Review*, 85, p. 441. *Radio Review*, 1, p. 80, November, 1919.)

220. THE THREE-ELECTRODE THERMIONIC VALVE AS AN ALTERNATING CURRENT GENERATOR. Professor C. L. Fortescue. (*Electrician*, 83, pp. 294—295, 388—390, 414—416, September, 1919. *Electrical Review*, 85, pp. 456—457, Abstract. *Engineering*, 128, p. 357, Abstract. *Radio Review*, 1, p. 83.)

221. THREE-ELECTRODE VACUUM TUBES. L. de Forest. (*Electrician*, 83, p. 477, October, 1919.)

Correspondence relative to the invention of certain circuits for the use of two three-electrode valves in parallel for generating oscillations † and also relative to new terminology for three-electrode valves.

222. IMPROVEMENTS IN VALVES FOR GENERATING ELECTRICAL OSCILLATIONS, ETC. L. M. Ericsson & Company, Russia. (*British Patent* 131680, July, 1918. Patent accepted, September 1st, 1919.)

A vacuum tube is described for use in the ordinary manner of the three-electrode valves, but with a plate cathode instead of the usual filament. This plate cathode is heated by electronic bombardment at the back from an auxiliary filament cathode. If desired a screen with a suitable aperture may be placed between the auxiliary filament cathode and the main cathode, and if necessary a suitable potential may be applied to the screen. The temperature of the main cathode may be made higher than in the case of the filament electrodes generally used.

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* See also RADIO REVIEW Abstract No. 114.

† See especially RADIO REVIEW, 1, pp. 80—83, November, 1919.

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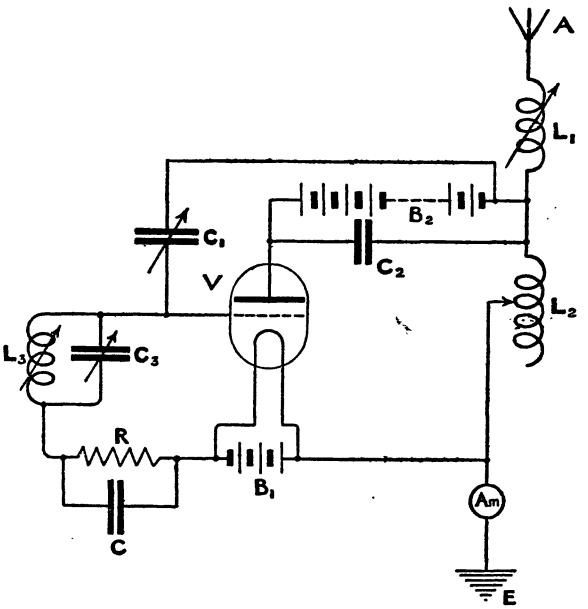
223. A VACUUM-TUBE TRANSMITTER OF CONTINUOUS WAVES. J. Scott-Taggart. (*Electrical Review*, 85, pp. 710—711, December, 1919.)

The circuit described is illustrated in Fig. 5. The set may be used for wireless telephony by connecting a shunted microphone in the earth lead, or for telegraphy by joining a key in series with B_2. Aerial currents of the order of 1 ampere and ranges of about 200 miles are mentioned but without reference to the aerial system, receiving apparatus, etc. Condenser C_1 provides the main retroactive coupling, but there is also some magnetic coupling between L_2 and L_3.



C_3 = 0·0004 mfd.
R = 10,000 ohms.
C = 0·001 mfd.
B_2 = 400—800 volts.
C_2 = 0·001 mfd.

FIG. 5.

224. HIGH-FREQUENCY SIGNALLING. Western Electric Company, U.S.A. (*British Patent* 132562, June, 1918. Patent accepted, September 25th, 1919.)

In the transmitting arrangement described, a high-frequency carrier wave is used modulated by a wave of intermediate but inaudible frequency, the latter being further modulated in accordance with the signal to be sent. Multiplex working may be obtained by using several non-interfering intermediate frequencies, and if desired several carrier frequencies. One arrangement is indicated in Fig. 6. G_1 is the source of high-frequency power of frequency say 1,000,000, G_2, G_3, etc., are the intermediate frequency generators, for example 20,000 or 30,000~. These are connected through modulating valves V_1, V_2, etc., to the common grid circuit of valve V_3 as indicated. The

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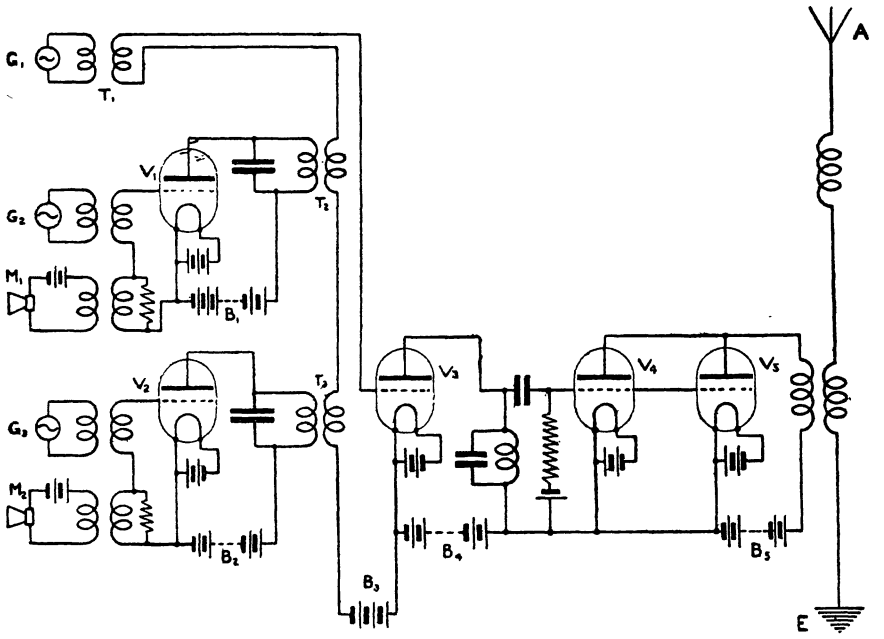

FIG. 6.

output of these valves is modulated by the microphones M_1 M_2 or other signalling apparatus. V_4 V_5 are amplifiers connected between V_3 and the aerial circuit A E. An analogous arrangement may be used at the receiver for sorting out the currents of different frequencies.

225. WIRELESS TELEGRAPHY AND TELEPHONY BY THREE-ELECTRODE VALVES. C. Gutton. (*Revue Généralé de l'Électricité*, 6, pp. 365—376, September, 1919.)

Arcs and high-frequency alternators are now used in practice mainly for high-power stations, but the application of 3-electrode valves for wireless purposes has rendered practicable C.W. transmission for all wavelengths and all powers. In the present article the author deals with this application in a very thorough manner, and commencing with the use of a valve to sustain oscillations describes in turn its application to both transmission and heterodyne reception. The selectivity of heterodyne reception is discussed, and the use of the valve as a simple detector and as an auto-heterodyne is described, as well as the advantages of regenerative amplification. The article is concluded with three sections devoted to the principles of wireless telephony, radiotelephonic stations, and recent progress and the future of wireless telephony. Circuit diagrams are given showing the modulating microphone coupled to the aerial circuit, and also coupled through an amplifier to the grid circuit of the transmitting valves, the latter

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arrangement being suitable for coupling a land telephone line on to a radio-telephonic transmitter. An arrangement in which the microphone is coupled to the plate circuit inductance of a single oscillating valve, the energy of which is subsequently amplified before transference to the aerial, is also described as being suitable for a high-power station.

226. HIGH-FREQUENCY ELECTRIC SIGNALLING. Western Electric Company (U.S.A.). (*British Patent* 131426, August, 1918. Patent accepted, August 18th, 1919.)

This relates to high-frequency signalling systems in which the signals are transmitted as modulations of a high-frequency carrier wave, and are combined at the receiving station with locally generated waves of the same frequency. A special feature is the production of both the carrier waves and the local waves from control oscillations of an intermediate frequency. One arrangement is indicated in Figs. 7 and 8. Fig. 7 indicates the transmitting circuits, and Fig. 8 the receiving circuits. The control oscillations are generated by the valve V_1 and amplified by the valve V_2 in the usual manner. The output circuit of V_2 is coupled through transformer T_1 to the grid circuit of a "harmonic generator" V_3. This comprises a valve overloaded so as to produce a deformation of the control waves which is equivalent to adding a number of harmonics to these waves. The deformed wave is then amplified by a valve V_4 in the plate circuit of which is a tuned circuit C L for picking out one of these harmonics. This harmonic is utilised as the

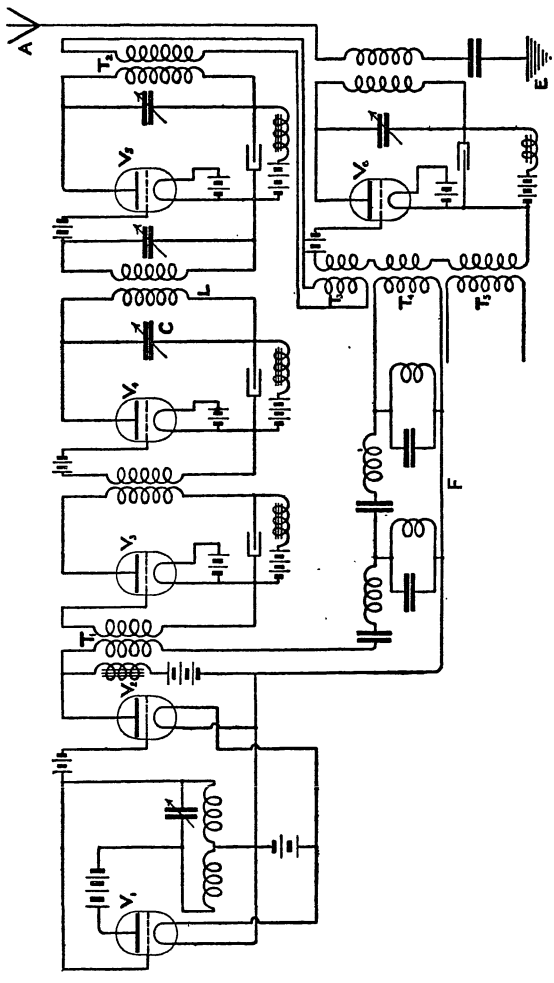

FIG. 7.

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carrier frequency and is amplified by the valve V_5 to which the plate circuit of V_4 is coupled. The output circuit of V_5 is coupled through T_2 T_3 to the grid circuit of the controlling valve V_6. The grid circuit of this valve is also coupled through transformer T_4 and filter circuit F to the primary circuit of transformer T_1, which is in the plate circuit of valve V_2. The oscillations of the control frequency are therefore supplied to the grid circuit of the controlling valve V_6 as well as the oscillations of the carrier frequency. The grid circuit of V_6 is also coupled through transformer T_5 to a modulating circuit for the control of the emitted waves by the telephonic or other signalling currents. At the receiving station (Fig. 8) the received oscillations are amplified by the valve V_7 and transferred to the detecting valve V_8. The output circuit of this valve is coupled through transformer T_6 to the frequency filtering circuits F_1 and thence to the receiving circuit proper through T_7. The output circuit of the detecting valve V_8 is also coupled through transformer T_8 to a second frequency filtering circuit F_2 on to a valve V_9 which is overloaded in a similar manner to valve V_3 of the transmitter and serves

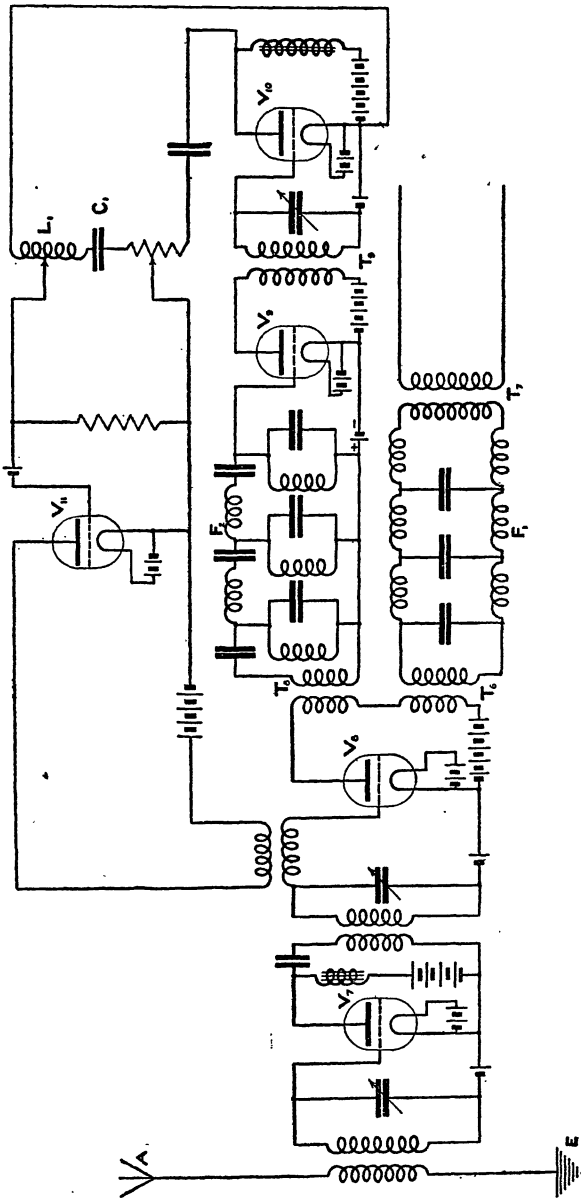

FIG. 8.

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the same purpose, namely, to distort the wave form of the control frequency oscillations passing through F_2, the circuit F_2 being adjusted to prevent the passage of currents of any frequency other than the control frequency. The output circuit of V_9 is coupled through transformer T_9 to the amplifying valve V_{10} in the plate circuit of which is the tuned circuit C_1 L_1 arranged to permit the passage of a harmonic of the same degree only as that used at the transmitting station. This tuned circuit is joined to the grid of the amplifying valve V_{11} from which they are transferred back to the grid circuit of the detecting valve V_8. The modulated oscillations received from the aerial are thus combined with unmodulated oscillations of identical frequency obtained from the harmonics set up by the valve V_9. The receiver therefore appears to work on a heterodyne principle with identical frequencies, so that the modulations only, that is to say the speech or other signalling currents, pass to the receiving instrument through the transformers T_6, T_7 and the filter circuit F_1. Modified arrangements are also described by means of which a similar method may be used for multiplex radiotelephony using different carrier frequencies all obtained from the same initial control frequency.

227. MODULATORS FOR RADIOTELEPHONY. C. Schmitt. (*L'Électricien*, 49, p. 204, November, 1919.)

A general descriptive article outlining the various forms of variable resistance microphones, microphonic control by 3-electrode valves, and the Alexanderson magnetic microphone.

228. TELEPHONE REPEATERS. B. Gherardi and F. B. Jewett. (*Proceedings American Inst. Electrical Engineers*, 38, pp. 1255—1313, November, 1919.)

The historical development of telephone repeaters is given, together with descriptions of valve amplifiers and various forms of magnetically controlled arc repeaters, etc. The essential properties of repeater networks are given, with illustrations of installations.

229. IMPROVEMENTS RELATING TO THE USE OF AUDION AMPLIFYING APPARATUS IN TELEPHONY. M. Latour. (*British Patent* 131639, June, 1917. Patent accepted, September 4th, 1919.)

An addition to British patent 127318. It relates to the use of valve amplifiers for two-way telephone repeaters.

230. IMPROVEMENTS RELATING TO TELEPHONE REPEATERS. M. Latour. (*British Patent* 131704, August, 1917. Patent accepted, September 4th, 1919.)

Special arrangements of 3-electrode valves for two-way telephone repeaters.

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231. The Problems of Vacuum Tube Circuits.—The Audion as a Detector. L. M. Clement. (*Everyday Engineering Magazine*, 8, pp. 112—113, November, 1919.)

An elementary account of the use of a triode valve for rectification at the lower bend of the characteristic curve.

232. The Design of Multiple-Stage Amplifiers. C. L. Fortescue. (*Electrical Review*, 85, pp. 700—701, November, 1919.)

See Radio Review, 1, pp. 178—181.

233. The Use of Impedence, Capacity and Resistance Couplings in High-Frequency Amplifiers. J. Scott-Taggart. (*Electrician*, 83, p. 221, August, 1919.)

Circuit diagrams are given of multivalve amplifiers with resistance-capacity coupling.

234. Notes on Valve Amplification. W. S. Barrell. (*Wireless World*, 7, pp. 407—409, October, 1919.)

235. High Vacuum Amplifiers. W. Schottky. (*Archives für Elektrotechnik*, 8, p. 1, July, 1919. *Elektrotechnische Zeitschrift*, 40, p. 604, November, 1919, Abstract.)

An account of investigations carried out in 1915 but unpublished for military reasons. The definition of the amplification is discussed and formulæ established for multiple cascade amplifiers. The design of the valve is then considered in order to obtain characteristics and operating conditions which lead to the best amplification. The result is obtained that the optimum amplification obtainable is proportional to the square root of the anode potential and inversely proportional to the fourth root of the grid potential. It is also stated that for cylindrical amplifiers the amplification is proportional to the root of the axial length and inversely proportional to the root of the diameter of the grid.

236. On New Arrangements of Potentiometric Amplifiers. A. Blondel and M. Touly. (*Comptes Rendus*, 169, pp. 557—562, September, 1919.)

The use of amplifying valves for the measurement of small differences of potential is further dealt with in this paper which describes simplifications of arrangements previously described.*

The arrangement dealt with comprises two amplifying stages—the second containing several tubes in parallel. A regenerative coupling is provided (by resistances) from the second stage back to the grid circuit of the first valve. The indicating galvanometer or other instrument may be connected either in series with the plate circuit of the second stage, or in shunt to a part of that circuit. Formulæ are given in explanation of the mode of operation.

* Radio Review Abstract No. 186.

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237. ON BLONDEL'S AND TOULY'S NEW ARRANGEMENTS OF POTENTIOMETRIC AMPLIFIERS. A. Blondel. (*Revue Générale de l'Électricité*, 6, pp. 427—441, October, 1919.)

This article describes in greater detail the apparatus referred to in RADIO REVIEW Abstract No. 236, and also its development. The principle of one arrangement is indicated in Fig. 9. The internal resistance of valve V_1 provides the fourth arm of the Wheatstone Bridge of which R_1, R_2, R_3, are the other arms. The "battery-arm" of the bridge includes the anode battery B_2, while the "galvanometer-arm" includes the grid circuit of the second valve V_2. This second valve is also joined in a Wheatstone Bridge circuit R_1', R_2', R_3', with the indicating instrument G. The initial p.d. to be amplified is applied to T_1T_2. By interchanging the "battery" and "galvanometer" arms of each of these bridges, both valve filaments can be supplied

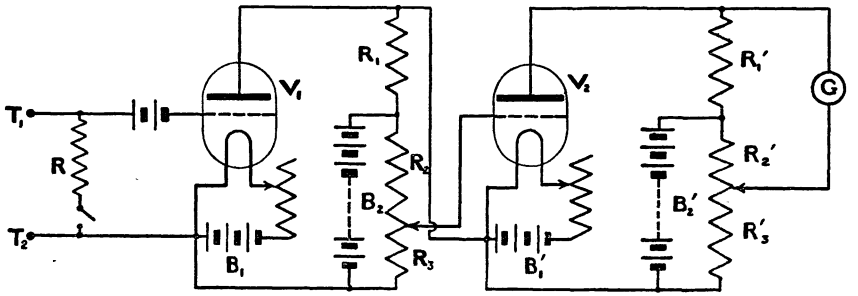

FIG. 9.

from the same battery, while a further simplification is obtained by suppressing two of the "bridge-arm" resistances which shunt the anode battery B_2 and connecting the grid of the second valve to an adjustable point on this battery, thus aiming at an amplifier with "potentiometric" coupling between the stages.

In an improved arrangement a regenerative coupling is provided between the plate circuit of the second valve and the input circuit to the grid of the first valve. This is obtained by a potentiometer resistance joined either in series with the plate circuit or shunting the plate-filament of the second valve. The latter arrangement is indicated at P in Fig. 10, which also shows a third valve, V_3 added to obtain additional amplification. This third valve may be replaced by a simple rectifying valve if desired to enable an ordinary D.C. galvanometer to be used for measuring A.C. potentials. In other arrangements described in the paper, several valves are joined in parallel in the second stage in order to augment the plate current for operating the indicating instrument. The arrangement of V_1 and V_2 in Fig. 10 follows the "potentiometric" modification of Fig. 9 described above. A common anode battery B_2 is used, with smaller additional batteries B_2', B_2'' and B_2''' for each valve. The left-hand portion of P adjacent to the filament connection is included in the input grid circuit and provides the regenerative

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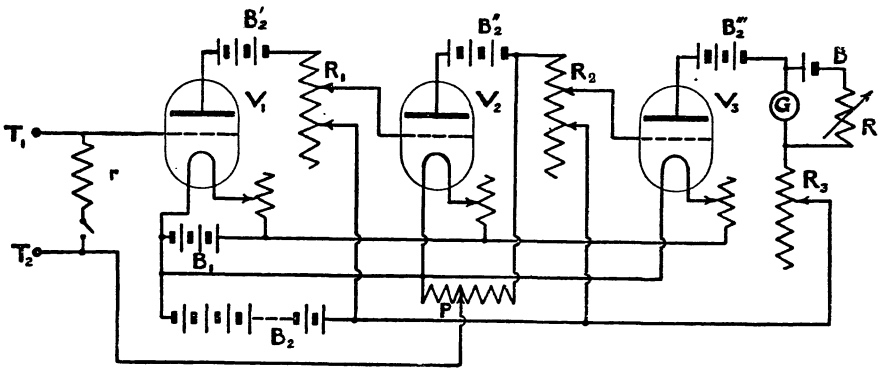

FIG. 10.

coupling. B and R are added to balance out the plate current of V_3 through the galvanometer G.

The paper also includes a mathematical explanation of the operation of each arrangement described. (See also Abstract No. 212.)

238. RECTIFIERS. B. J. Brochard. (*French Patent* 495317, filed June 18th, 1917. Published October 4th, 1919.)

For rectifiers, galena which will pass a 16-mesh screen but will not pass a screen of 18 mesh, and having a clean surface, is mixed with strong glue; and conducting surfaces, either rigid or flexible, are covered with the mixture. One cubic cm. of galena prepared according to the process described covers 12 cm. of surface.

239. RECEIVERS. B. J. Brochard. (*French Patent* 495318, filed June 18th, 1917. Published October 4th, 1919.)

The invention relates to the employment of very flexible metal brushes for use as crystal detector contacts for the reception of Hertzian waves. The said brushes are made from 15 cm. of gold or silver brocading thread, either in its usual form, or with only the metallic portion. The regulation obtained with these brushes is practically instantaneous.

240. DETECTOR. H. D. Betz. (*French Patent* 495432, filed August 24th, 1918. Published October 8th, 1919.)

This invention relates to a protector for coherers.

241. A NEW AMPLIFYING RELAY. F. Martin. (*L'Électricien*, 49, pp. 132—134, September, 1919.)

Description of an electromagnetic microphone relay for amplifying radio signals.

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242. A TRIGGER RELAY UTILISING THREE-ELECTRODE THERMIONIC VACUUM TUBES. W. H. Eccles and F. W. Jordan. (*Electrician*, 83, p. 298, September, 1919. *Electrical Review*, 85, p. 441. *Radio Review*, 1, pp. 143—146.)

243. RELAYS. D. W. Brown. (*French Patent* 495385, filed August 4th, 1917. Published October 7th, 1919.)

The invention relates to a method and apparatus for relaying or increasing the effect of high-frequency electric oscillations on detectors (see British Patents 117686 and 120356).

244. RECORDING OF EIFFEL TOWER TIME SIGNALS FOR DETERMINATION OF CLOCK ERROR. L. B. Turner. (*Electrician*, 83, pp. 554—557, November, 1919.)

The use of the author's valve relay for the recording of time signals is described in this paper. A simultaneous record is made on a double-magnet chronograph of the clock ticks and of the wireless signals. Sample strips are reproduced in the paper illustrating the accuracy obtainable in most cases. The atmospherics can be distinguished from the signals by the records on these strips. A determination of the lag in the wireless relay apparatus indicated that its value was generally about $\frac{1}{200}$ of a second and was certainly less than $\frac{1}{100}$ of a second. In most cases, therefore, the lag is quite negligible.

245. RECEIVING CIRCUITS. H. J. J. M. de R. de Bellescize. (*French Patent* 495316, filed June 26th, 1917. Published October 4th, 1919.)

The invention consists in rendering open or closed wireless receiving circuits symmetrical to permit the obtaining of better syntony and of reducing the effect of atmospheric disturbances. The symmetry is obtained by disposing in each of the two connections to the condenser in the receiving circuit, an arrangement of capacities, resistances and self-inductances so as to reproduce the electrical characteristics of the apparatus connected to the other terminal, in the manner described in British Patent 132434. (This French specification contains Figs. 1 and 2 only of the British Patent but covers the same subject-matter.)

The same result may also be obtained by coupling the receiving circuit inductively to a second circuit by means of two identical coils placed electrically symmetrical to the capacity in the primary circuit.

246. ANTENNÆ. Compagnie Française pour Exploitation des Procédés Thomson-Houston. (*French Patent* 495641, filed October 1st, 1917. Published October 14th, 1919.)

For particulars of this invention, see the British Patent 130064.*

* See RADIO REVIEW Abstract No. 198.

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247. LOOP ANTENNÆ AND DIRECTION FINDERS FOR AMATEUR USE. D. S. Brown. (*Radio Amateur News*, 1, pp. 60—62, August, 1919.)

Design and constructional details for Frame Aerials are given, based on the transmission formulæ and on experimental results. The strength of signals received on the loop is proportional to $NAL/\lambda^2 R$ where N = No. of turns, A = area, L = inductance; λ = wavelength, and R = H.F. resistance. Various tables for different size loops, etc., are given, among which are the following:—

Best Wire Spacing for Multi-turn Loops.

Size of Loop (Feet).	Spacing (Inches).
4	$\frac{1}{4}$
6	$\frac{7}{16}$
8	$\frac{9}{16}$
10	$\frac{3}{4}$
12	$\frac{15}{16}$

Best Size of Square Loops for various Wavelengths.

Wavelength (Metres).	Size in Feet.	Turns.	Wavelength (Metres).	Size in feet.	Turns.
50—150	4	1	1,200	8	12
	3	1		6	14
				4	20
200	8	1			
	6	2	1,600	8	16
				6	20
300	8	2		4	30
	6	4			
600	8	4	2,500	8	30
	6	7		6	40
	4	10		4	60
800	8	7	3,500	8	45
	6	10		6	65
	4	15			

248. ANTENNÆ. Compagnie Française pour Exploitation des Procédés Thomson-Houston. (*French Patent* 495770, filed February 14th, 1919. Published October 17th, 1919.)

The invention consists in the arrangement of multiple earth connections for radiating antennæ, the object being to divide the earth current in a perfectly uniform manner throughout all the connections and to reduce the earth resistances to a minimum.

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249. WIRELESS TELEGRAPHY IN GERMANY. (*Elektrotechnische Zeitschrift*, 40, p. 527, October, 1919)

The military high-power station at Königswusterhausen has been taken over by the postal authorities for the public service mainly with the continent of Europe. The transmission between Nauen and the United States is so perfected that telegrams can be handed in at any post office; the same applies to telegrams for Spain. An experimental service with Sweden and Switzerland has been taken in hand.

250. NAUEN *v.* EILVESE. A. Meissner; A. Sörensen. (*Elektrotechnische Zeitschrift*, 40, pp. 113—115; 233—234; 429—431. 1919.)

Articles describing the activities of the Nauen and Eilvese stations during the war and discussion arising therefrom.

251. APPARATUS FOR OPERATING DISTANT DEVICES BY MEANS OF ELECTROMAGNETIC WAVES. L. M. Ericsson & Co., Russia. (*British Patent* 131166, August, 1918. Patent accepted, August 21st, 1919.)

An illuminated tube containing helium and other gases is used as the detector.

252. WIRELESS CONTROLLED TORPEDO. A. E. Ericson and G. A. Whipple. (*French Patent* 495475, filed September 11th, 1917. Published October 9th, 1919.)

253. SYSTEM OF TELEDYNAMIC CONTROL. J. H. Hammond. (*U.S. Patent* 1419678, renewed February, 1919. Published October 21st, 1919.)

Receiving arrangements for distant radio control.

254. A SYSTEM OF RADIO-DIRECTIVE CONTROL. J. H. Hammond. (*U.S. Patent* 1319068, renewed February, 1918. Patent published, October 21st, 1919.)

A system of radio control is described with a transmitting station provided with means for emitting several different types of waves (different wavelengths, etc.). The emission of these waves is under the control of separate local control stations.

255. LIGHT TELEPHONY. A. O. Rankine. (*La Nature*, 47, pp. 307—309, November, 1919.)

An illustrated article dealing with apparatus previously described by the author.*

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* RADIO REVIEW Abstract No. 178.

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256. EARTH TELEGRAPHY. P. Maurer. (*L'Électricien*, 49, pp. 181—184, October, 1919.)

An article explaining the general principles, with some particulars of apparatus used during the war, and of the ranges obtainable. A special buzzer transmitter and a three-valve amplifying receiver are described and illustrated.

257. WIRELESS IN THE R.A.F. DURING THE WAR. T. Vincent Smith. (*Electrical Review*, 85, pp. 457—458. *Radio Review*, 1, p. 38, October, 1919.)

258. AIRCRAFT WIRELESS SETS: THE 52A SPARK TRANSMITTER. J. J. Honan. (*Wireless World*, 7, pp. 470—472, November, 1919.)

An illustrated description of the transmitter fitted to the trans-Atlantic Vickers-Vimy machine.

259. AIRPLANE ANTENNA REELS. L. Ryan. (*Electrical Experimenter*, 7, p. 324, August, 1919.)

Describes a type of reel designed to stand all mechanical and electrical stress under difficult service conditions. The reel is self-locking and shows at a glance the length of aerial let down.

260. IMPROVEMENTS RELATING TO ELECTROMAGNETIC WAVE RECEPTION SYSTEMS. J. Robinson. (*British Patent* 132291, November, 1918. Patent accepted, September 18th, 1919.)

To prevent interference in the wireless receiver from the magneto or other ignition system on aircraft it is proposed to connect a variable condenser between the grid and filament of the valve detector or amplifier. One or more oscillatory circuits tuned to the wavelength or wavelengths of the waves emitted by the ignition system or other disturbing source may be arranged in the connections between the loop receiving circuit and the valve amplifier.*

261. THE ELIMINATION OF MAGNETO DISTURBANCE IN THE RECEPTION OF WIRELESS SIGNALS ON AIRCRAFT. J. Robinson. (*Radio Review*, 1, pp. 105—110, December, 1919.)

262. CAN RADIO IGNITE BALLOONS? N. Tesla. (*Electrical Experimenter*, 7, p. 516, October, 1919.)

263. WIRELESS NAVIGATION FOR AIRCRAFT. J. Robinson. (*Electrician*, 83, p. 420, October, 1919, Abstract. *Radio Review*, 1, pp. 39—42.)

264. PROGRESS OF ELECTRICAL INVENTION. J. A. Fleming. (*Nature*, 104, p. 239, November, 1919.)

A brief review of the progress of radiotelegraphy is included.

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* See also RADIO REVIEW Abstract No. 261.

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265. CIRCUITS FOR UNDAMPED OSCILLATIONS. Pestarini. (*L'Elettrotecnia*, 6, pp. 481—487, August, 1919. *Science Abstracts*, 22B, No. 775.)

This article discusses the generalisation of the use of a series wound dynamo connected to a condenser for generating undamped electrical oscillations. It is shown that the same result could be obtained without the condenser by inter-linking the dynamo circuit with suitable auxiliary circuits or with a second machine. The use of a special kind of ironless alternator is also mentioned as being suitable for setting up large trains of undamped oscillations.

266. ELECTRICAL OSCILLATORS. N. Tesla. (*Electrical Experimenter*, 7, p. 229, July, 1919.)

A description of the author's work on W/T transformers, with a number of previously unpublished photos of Tesla transformers.

267. WIRELESS TELEGRAPHY PROBLEMS FOR OPERATORS. W. H. Eccles. (*Wireless World*, 7, pp. 331—332; 400—403, October, 1919.)

Shows how operators may assist in research work, often with the simplest of apparatus, by making observations in various parts of the world.

268. DUPLEX TELEPHONY BY "WIRED WIRELESS." K. W. Wagner. (*Elektrotechnische Zeitschrift*, 40, pp. 383—388, August, 1919. *Technical Review*, 5, p. 80, October, 1919.)

A description is given of experiments in the direction of duplex or multiplex telephony by several superimposed high-frequency currents along a telephone line made by the German Telegraphen Versuchsamt since 1912, and in 1918. It is proved that radio-frequency currents are damped out in the line to a considerably greater extent than audio-frequency currents, partly owing to skin effect and partly to radiation losses. In the case of similar experiments along paper-insulated cables there is an increased damping arising through the large dielectric losses. With coil-loaded cables the loading coils must be bridged by condensers. The system used for the Berlin-Hanover line is described with diagrams. It includes a device for eliminating harmonics from the emitted waves and for preventing the received signals from reacting on to the sending apparatus.

2. Book Reviews.

PRÉCIS D'ÉLECTRICITÉ THÉORIQUE. By Léon Bloch, D. ès Sc. (Paris: *Gauthier-Villars et Cie*. Pp. vi. + 476. Price 30 fr.)

A simple mathematical treatise, in which, starting from the most elementary facts, the reader is taken step by step through electrostatics,

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magnetism and electromagnetic theory. The latter is based on the Lorentz modification of Maxwell's theory, and follows along lines very similar to those of Föppl and Abraham's "Electricity and Magnetism." Vector methods are used throughout and the whole treatment is remarkably lucid. The first ten of the fifteen chapters deal with electrostatics, magnetism, induction, etc.; the last five deal with electric oscillations, coupled circuits, propagation of waves, radiation from antennæ, electromagnetic optics, electrodynamics of moving bodies, the equations of Hertz, Lorentz and Minkowski, and the optics of moving bodies including the theories of Lorentz and Einstein.

The book can be read with ease by any one familiar with the elements of the calculus and vector algebra, and can be confidently recommended to those wishing to lay a sound foundation of electromagnetic theory.

G. W. O. H.

LA TÉLÉGRAPHIE SANS FIL, LA TÉLÉPHONIE SANS FIL—APPLICATIONS DIVERSES. By G. E. Petit and L. Bouthillon. (Paris: *Librairie Delagrave*. Pp. vii. + 304. Price 15 fr.)

In the preface Professor D'Arsonval has written to this book he refers to "the supreme achievement" of wireless telegraphy in communicating over a distance of 20,000 km. between a station and one at its antipodes. As he says, this great record has now been established, and nothing could make clearer the enormous progress that wireless telegraphy has made in the brief twenty years during which it has been a practical means of communication. It was in 1896 that Marconi first brought over to England his new "system" which many scientists looked at with some scepticism. It would indeed have been a bold man who, at that date, would have prophesied that within two decades wireless telegraphy would be used to send a message from here to New Zealand. Long distance wireless is now looked on, more or less, as a matter of course, and this book treats the subject in a scientific manner, which takes account of this phenomena very early in its pages. Like nearly all French books this treatise is very logical; the method of treatment is synthetic; the fundamental laws are stated, and the resulting phenomena are worked out. In this respect it is a book which has few equals. It starts with a simple study of the production of electromagnetic waves, the emission of waves by one conductor, and their reception by another placed on a conducting earth. The electric waves which are produced by an oscillating current in a straight wire are described and the Hertzian equation from which the magnitude of the electric waves were first calculated are dealt with simply and clearly. Next comes a short discussion of electrical oscillations and the production of a damped train of waves, the damping of a train by radiation, or, as the authors term it, "radiance," and the effect of an earthed antenna. The problem of reception is discussed and the efficiency of radio communication is defined. A very useful feature of this chapter is a summary at the end, of the main conclusions arrived at. The second chapter deals with the propagation of waves round the surface of the earth. Reference is

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made to the mathematical theories that have been developed to determine the magnitude of the phenomena which might be expected to be observed on the assumption of a perfectly conducting earth surrounded by a perfectly insulating medium. The theories of the space wave due to Sommerfeld and of the Heaviside layer developed later by Eccles, to explain the enormous discrepancy between theory and observed effect, when signals are sent over hundreds of miles round the earth, are discussed, but the paper by G. N. Watson referred to recently by the editor of the RADIO REVIEW, in which a mathematical calculation has been made of the effect of an upper conducting layer on the propagation of waves round the earth is not mentioned, it was published just too late for this edition; it provides a crucial proof, which ought to put beyond doubt the correctness of the Heaviside layer theory of electromagnetic propagation. The experimental results obtained by measuring the variation of signal strength from day to day and month by month are mentioned, and the necessary modifications in the empirical formula given by Austin and others are referred to. Working in logical order, from the waves, the next stage in the study of propagation is the form of the antenna, and this subject is discussed in detail in Chapter III. The various forms are mentioned, the different methods of excitation of the antenna are described, and the effect produced by capacity and inductive connections to the earth, and finally the various forms of earth connection. Following still the logical sequence, the next chapter deals with the "transmission" of electric waves. We should use the word "production," for the chapter deals with the methods that are used for producing electrical oscillations, *i.e.*, by sparks and arcs and alternators and thermionic valves.

In dealing first with the spark method, reference to the damping due to circuit resistance and to spark resistance is made and curves of variation of spark resistance with varying lengths of spark are included. One factor has always seemed to the author of primary importance in connection with spark resistance, *i.e.*, the value of the maximum current passing at the instant of discharge. The capacity across the spark is of course the quantity that controls the current, but it would be most interesting if figures could be given of the actual resistance of the spark for different currents. The various forms of rotating spark gaps used by the Marconi Co. are described, and the quenched spark arrangement of Wien. The Poulsen arc, the various forms of high-frequency alternator, and, finally, the three-electrode valve or pliotron for generating continuous waves are mentioned. The methods of coupling the oscillating circuit to the antenna are dealt with in the last part of the chapter. Next follows an account of the methods used for the reception of the electric waves. The usual types, *i.e.*, the coherer, the magnetic detector, and the various forms of crystal detectors are clearly described, and a good account given of the Fleming valve and its derivatives, included in which is a description of the method of heterodyning which has proved such an efficient means of overcoming jamming in the continuous wave sets which were developed toward the end of the war. Amplifiers are just referred to, and the various methods of recording signal strength are mentioned, the use of the Einthoven galvanometer is not

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described, though this has proved by far the most successful instrument (except possibly the beautiful galvanometer designed by M. Abraham) for this purpose. The methods of tuning in order to prevent jamming are next dealt with, including an account of the Marconi multiple tuner, and the methods of connecting the detector to the circuit, according to its *modus operandi* are described. Chapter VI. deals with the methods of detecting the direction from which a wireless signal is coming, and the Bellini-Tosi compass is described in detail. The second part of the book deals with radio communication, that is, with the problems that have to be considered when a wireless station has to be designed. It starts with a short *résumé* of the history of radiotelegraphy, and continues with the description of many stations of different types, including the standard 5-kw. station for land or sea work, the Eiffel Tower station, and the stations at Arlington, Sayville and Tuckerton, as well as those at Nauen and Eilvese. The last three chapters deal with radiotelephony, the transmission of photographs by wireless telegraphy, and the transmission of power. The treatment of radiotelephony is disappointing, as it gives no account of the great progress that has been made in this direction during the last year or two. The remaining chapters, too, are mere paragraphs, introduced with the view of pointing out the possibility of future developments, rather than with the object of giving descriptions of methods that are actually in use. The last part of the book contains a number of notes which will be valuable to practical radiotelegraphists. The first describes in detail the signals that are sent out daily by the Eiffel Tower. The next two describe the principles of the method adopted by M. Bouthillon in his high-frequency alternators and by Joly and Goldschmidt in the Goldschmidt alternator. The last seventy pages contain the regulations adopted by the International Telegraphic Convention, held in London, in July, 1912. As a text book for students who want to know the fundamental principles of wireless telegraphy this book is excellent, it covers the ground clearly and well. It is rather disappointing from the more practical side, and it is not up-to-date as regards all the latest developments in continuous wave practice, which have come about from an intensive study of the three-electrode valve. For the student of wireless, however, who wants to understand exactly what is happening when a wireless signal is sent out by a transmitting station and received by another station, the book is thoroughly satisfactory.

E. W. MARCHANT.

Correspondence.

TRIODE NOMENCLATURE AND SYMBOLS.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In his letter dated December 9th, 1919, in your issue of January, 1920, Dr. Eccles searches for a suitable symbol for the "voltage factor" of a triode, in place of Langmuir's k, the not uncommon m, and his own pro-

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visional g, each of which has something against it. This quantity is the ratio between two other quantities frequently used separately in the theory of all triode circuits; for them no generally accepted names or symbols have yet been established, and a settlement is at least equally needed.

Writing, i_g, i_a, v_g, v_a for grid and anode currents and potentials, we have to deal with the four ratios, all of the dimensions of conductance,

$$\frac{\partial i_a}{\partial v_g}, \quad \frac{\partial i_a}{\partial v_a}, \quad \frac{\partial i_g}{\partial v_g}, \quad \frac{\partial i_g}{\partial v_a}.$$

The first two are the most used, and my own provisional practice has been to represent them by the symbols g and a, using g/a for Dr. Eccles' "voltage factor" g. In his recent article in this Review,* Dr. Eccles has adopted

$$h_g, \; h_a, \; g_g, \; g_a$$

for the four conductances respectively. The unfortunate coincidence, doubtless accidental, between the main letter and its subscript in the third symbol only, detracts from that easy consistency so desirable as a minor mental relief; and a preferable series would appear to be

$$a_g, \; a_a, \; g_g, \; g_a.$$

But the name is yet more important than the symbol. Algebra is mainly a thing of writing, not of speech; and a writer may begin by defining an entirely arbitrary amnemonic set of symbols such as Professor Fortescue's

$$k_1, \; k_2, \; k_3, \; k_4,$$

in his recent paper on multi-stage amplifiers.† The reader can always glance back. Conversation is much impeded, however, whenever A talks triodes to B or C or D, by the necessity to preface his remarks with such statements as: "When I say g, I mean the rate of change of anode current with grid potential."

It has been suggested, I think by Mr. E. V. Appleton, that the terms

anode conductance $\left(= \frac{\partial i_a}{\partial v_a}\right)$

mutual conductance $\left(= \frac{\partial i_a}{\partial v_g}\right)$

grid conductance $\left(= \frac{\partial i_g}{\partial v_g}\right)$

should be used; and this suggestion seems to provide a good basis. Mutual conductance, however, is obviously an inaccurate description: if $\frac{\partial i_a}{\partial v_g}$ is the mutual conductance, what is $\frac{\partial i_g}{\partial v_a}$? I suggest, therefore, as fairly brief and quite unmistakable, the terms set out in the table below; and I should be

* November, 1919, p. 77.

† See RADIO REVIEW, January, 1920, p. 179.

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disposed to accept ν for the ratio a_g/a_a as being the most writable and speakable of the symbols offered to us by Dr. Eccles.

Quantity.	Full Name.	Colloquial Abbreviation.	Symbol.
$\frac{\partial i_a}{\partial v_g}$	Anode-grid slope conductance	Anode-grid conductance	a_g
$\frac{\partial i_a}{\partial v_a}$	Anode-anode slope conductance	Anode conductance	a_a
			$\left.\begin{matrix} a_g \\ a_a \end{matrix}\right\} \equiv \nu$
$\frac{\partial i_g}{\partial v_g}$	Grid-grid slope conductance	Grid conductance	g_g
$\frac{\partial i_g}{\partial v_a}$	Grid-anode slope conductance	Grid-anode conductance	g_a

L. B. TURNER.

King's College, Cambridge,
January 10th, 1920.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—I was very much interested to read Dr. Eccles' views on the Physics of Amplification. The arguments for an amplifying factor of zero dimensions should surely be overwhelming. It is true that one finds in a recently published book on valves, the following statement, ". . . thus small changes of grid voltage produce *comparatively* large changes of anode current" (the italics are mine) and later in the same book, the slope of the grid voltage-anode current characteristic is suggested as the current factor of amplification. In this connection it is well to note that in a typical valve under amplifying conditions a change of grid voltage of unity produces a change in the anode current of 5×10^{-4} amperes so that the phrase "comparatively large changes of anode current" appears meaningless unless the effective resistance of the anode circuit is specified. One is inclined to hesitate before assuming that this confusion has been brought about from the fact that characteristics are very often plotted on such a scale as to make the slope of the steep portion greater than 45 degrees.

E. V. APPLETON.

Cambridge,
January 19th, 1920.

ERRATUM.

Page 239. The first line of Dr. McLachlan's Paper should read, "In using two-electrode thermionic valves . . ."

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THE RADIO REVIEW

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THE
RADIO REVIEW

VOL. I APRIL, 1920 NO. 7

The Kallirotron, an Aperiodic Negative-Resistance Triode Combination.*

By L. B. TURNER, M.A.

1. INTRODUCTION.

In wireless telegraphy it is common practice to exalt the amplifying action of a triode by introducing magnetic or electric retroaction between the oscillatory circuits connected to the grid and anode. It is well understood that the most important effect of such retroaction is the reduction of the ohmic resistance of the circuits; and this may be conveniently, if more abstractly, expressed as the introduction of a negative resistance into the circuit. Since the circuits comprise inductance and capacity, their impedance cannot be reduced indefinitely towards zero as their resistance is decreased, except for sustained alternating currents of the particular frequency (or frequencies) to which they are tuned.

In a recent triode invention known as the "Dynatron," † by virtue of the phenomenon of copious emission of secondary corpuscles from a plate under sufficiently violent bombardment by primary corpuscles, the same negative resistance effect is obtained in quite another way. And the dynatron, being applicable to circuits containing resistance only, as well as to oscillatory circuits, is competent to reduce indefinitely the impedance of a circuit for currents of any frequency, including even steady currents.

The arrangement to be described here consists of a combination of circuits, which may be aperiodic, including two ordinary triodes in which secondary emission plays no part, whereby electrical resistance is annihilated—the result achieved in the dynatron by dependence on secondary emission. Some reference name being necessary, the arrangement has been termed the "Kallirotron." ‡ It will be best understood by examining the device in some detail as an amplifier of electromotive force of any frequency.

2. THEORY OF KALLIROTRON.

Consider the circuits shown in Fig. 1. Here two ordinary triodes, with

* Paper received in final form December 24th, 1919.

† "The Dynatron. A Vacuum Tube possessing Negative Electric Resistance." A. W. Hull, *Proc. Inst. Radio Engineers*, February, 1918.

‡ Second syllable accented, vowel short. From καλλιροος = easy flowing.

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their filaments joined and heated by a battery not shown, are connected by batteries and resistances disposed in a kind of vicious circle; and at two points small E.M.Fs. e_1 and E_1 may be introduced.

Let the condition of the triodes be given by the equation

$$\delta I = a \,.\, \delta V + g \,.\, \delta v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

expressing the relation between small changes of anode current, and anode

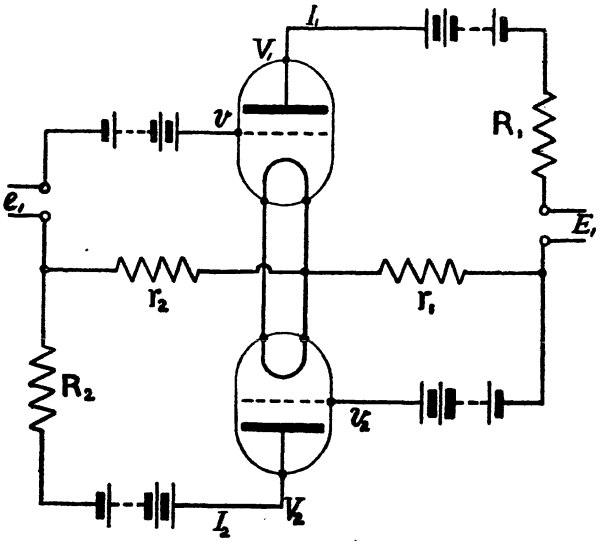

FIG. 1.

and grid potentials; a and g being the familiar conductance parameters of the two anode current characteristics.*

Assuming that changes of grid current are negligible in comparison with changes of anode current, the effect of the small E.M.Fs. e_1 and E_1 is given by

$$\delta I_1 = a_1 [E_1 - (r_1 + R_1)\, \delta I_1] + g_1 \,.\, \delta v_1$$

i.e.,
$$\delta v_1 = \frac{1}{g_1}\left[\delta I_1 \left\{1 + a_1 \left(r_1 + R_1\right)\right\} - a_1 E_1\right]. \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Also
$$\delta v_2 = -r_1 \,.\, \delta I_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Also
$$\delta I_2 = -a_2 (r_2 + R_2)\, \delta I_2 + g_2 \,.\, \delta v_2,$$

* a and g are the conductance slopes k_2 and k_1 of Professor C. L. Fortescue's paper, "The Design of Multi-Stage Amplifiers," read before the Institution of Electrical Engineers on November 19th, 1919. (See RADIO REVIEW, I., pp. 178—181.)

$a \equiv \frac{\partial I}{\partial v}$; $g \equiv \frac{\partial I}{\partial v}$. The graphical significance of a and g, and an idea of their magnitude in the pattern of triode most used in the war, are given at a glance by Fig. 2.

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i.e., $$\delta I_2[1 + a_2(r_2 + R_2)] = g_2 . \delta v_2$$
$$= -g_2 r_1 . \delta I_1 \quad \text{. . . from (3) . . . . . (4)}$$

Also $$\delta v_1 = e_1 - r_2 . \delta I_2$$
$$= e_1 + \frac{r_2 g_2 r_1 \delta I_1}{1 + a_2(r_2 + R_2)} \quad \text{. . . from (4) . . . . (5)}$$

Equating (2) and (5) we obtain

$$\delta I_1 \frac{[1 + a_1(r_1 + R_1)][1 + a_2(r_2 + R_2)] - g_1 g_2 r_1 r_2}{1 + a_2(r_2 + R_2)} = a_1 E_1 + g_1 e_1 . \quad (6)$$

If we make $e_1 = 0$, we get from (6)

$$\frac{E_1}{\delta I_1} = \frac{[1 + a_1(r_1 + R_1)][1 + a_2(r_2 + R_2)] - g_1 g_2 r_1 r_2}{a_1[1 + a_2(r_2 + R_2)]} \quad \text{. . . . . (7)}$$

This expression is the effective resistance of the I_1 circuit for small changes

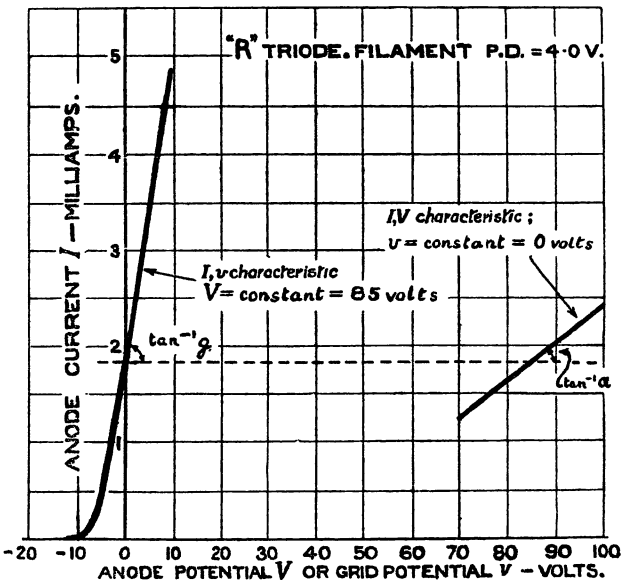
"R" TRIODE. FILAMENT P.D. = 4·0 V.
ANODE CURRENT I — MILLIAMPS.
I,V characteristic ;
v = constant = 0 volts
I,v characteristic
V = constant = 85 volts
tan⁻¹ g
tan⁻¹ a
5
4
3
2
1
-20 -10 0 10 20 30 40 50 60 70 80 90 100
ANODE POTENTIAL V OR GRID POTENTIAL V — VOLTS.

FIG. 2.

of I_1; it may be re-written

$$\rho_{1e} \equiv \frac{E_1}{\delta I_1}$$
$$= \rho_1 - \frac{g_1}{a_1} . \frac{g_2}{a_2} . \frac{r_1 r_2}{\rho_2} \quad \text{. . . . . (8)}$$

where $\rho_1 \equiv \left(\frac{1}{a_1} + r_1 + R_1\right)$ and $\rho_2 \equiv \left(\frac{1}{a_2} + r_2 + R_2\right)$ are the intrinsic (non-retroactive) resistances of the anode circuits.

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It is thus seen that the effect on the I_1 circuit of the retroaction between the two triodes is to introduce a negative resistance of magnitude

$$\frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot \frac{r_1 r_2}{\rho_2} \quad \ldots \ldots \ldots \ldots \ldots \ldots \quad (9)$$

where $$\rho_2 \equiv \frac{1}{a_2} + r_2 + R_2.$$

Under suitable conditions this negative resistance introduced by the retroaction may be made to approximate as closely as may be desired to the intrinsic positive resistance ρ_1, thus reducing the effective resistance to a vanishingly small value.

To examine the arrangement as an amplifier of E.M.F., let us make $E_1 = 0$, and find the magnification ratio m between the applied small E.M.F. e_1 and the resulting change of P.D. $(\delta V_1 - \delta V_2)$ between the anodes. The magnification is

$$m = \frac{(r_1 + R_1)\,\delta I_1 - (r_2 + R_2)\,\delta I_2}{e_1}$$

$$= \frac{\frac{g_1}{a_1}\left(r_1 + R_1\right)\left(\frac{1}{a_2} + r_2 + R_2\right) + \frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot r_1\left(r_2 + R_2\right)}{\left(\frac{1}{a_1} + r_1 + R_1\right)\left(\frac{1}{a_2} + r_2 + R_2\right) - \frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot r_1 r_2}$$

. . . from (4) and (6) . . . . . (10)

If we take the simple and practical case of a_1, a_2, g_1, g_2 all approximately constant, it is clear that by increasing r_1 and (or) r_2 we can make the denominator as nearly zero as we like, and therefore the magnification as nearly infinite as we like. If the denominator becomes less than zero, the system passes irreversibly into a widely different equilibrium with different values of a and g. The practical limit to m is imposed by the inconstancy of resistances, batteries, and triodes, particularly the last; and by the necessity of avoiding the instability which may accompany the slight changes in a and g set up by the signal to be amplified. In cases where the incoming signal e_1 may be of either sense, instability has to be carefully guarded against if high amplification is to be obtained. If instability is not avoided, the device behaves like the "trigger relay" of Eccles and Jordan,* the connections of which are substantially those of Fig. 1 with R_1, R_2 and E_1 omitted.

3. Means of obtaining Stability.

In order to obtain an amplifier at once sensitive and stable, that is an amplifier in which a small signal produces a large change continuing only as

* "A Trigger Relay utilising Three-Electrode Thermionic Vacuum Tubes." British Association Meeting, 1919. See Vol. I., No. 3 of this REVIEW. The Kallirotron was devised subsequently to, but independently of, the "trigger relay." In its theory the trigger relay is a particular case of the unstabilised Kallirotron.

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long as the signal continues, the expression for m (10), must be large but must not become infinite under the action of the signal. That is

$$\frac{g_1}{a_1}\cdot\frac{g_2}{a_2}\cdot r_1 r_2 \lessapprox \left(\frac{1}{a_1}+r_1+R_1\right)\left(\frac{1}{a_2}+r_2+R_2\right) \quad . \quad . \quad . \quad (11)$$

The effect of the signal on these expressions is to alter, if only very slightly, the quantities a_1, a_2, g_1, g_2. But the ratio g/a in a triode changes very much less rapidly with changes of grid and anode potential than do a and g separately. We may therefore regard the L.H.S. of (11) as unaffected, but the R.H.S. as affected, by the signal e. Hence m will vary only slightly with e if we make the external resistance $(r+R)$ of the anode circuit much greater than the internal anode resistance $1/a$. This is the familiar condition for making the magnification ratio $\frac{\delta V}{\delta v}$ of a single triode approximate to its limiting value g/a. The only practical difficulty in meeting it is that higher values of $(r+R)$ necessitate anode batteries of higher voltage. For example, if we wish to work on a fairly steep portion of the I,v characteristic without appreciable grid current, we need an anode potential of (say) 85 volts and current about $1\frac{1}{2}$ milliamps. So that with $(r+R)=4(1/a)=80{,}000$ ohms (say), the battery could not be less than 200 volts. Even then the change in each of the terms on the R.H.S. of (11) would still be as much as 20 per cent. of the change produced in a.

But the R.H.S. of (11) contains both a_1 and a_2, and if the product of the two terms $(1/a_1+r_1+R_1)$ and $(1/a_2+r_2+R_2)$ remains constant, changes in the individual terms do not matter. If there is any approach to symmetry between circuits 1 and 2, it is clear that when a_1 increases a_2 will decrease, since the potential and current changes are opposite in the two triodes. A convenient course is to make the two triodes and their circuits roughly similar; and if in addition we arrange to work over nearly straight portions of the I,v characteristic (*i.e.*, a and g nearly constant), we can obtain a fairly constant magnification (10) over a wide range of signal strength.

Stability may, however, be ensured without imposing any conditions of symmetry or rectilinearity of characteristic, merely by working always with that grid potential v which gives maximum magnification for the particular values of the resistances r and R, and controlling the amount of this magnification by adjusting the values of the resistances.* This process of adjustment, which is quite easily carried out, entirely prevents any signal, however strong, from producing the trigger effect; *i.e.*, ensures that the conditions after the cessation of any signal shall be the same as before its arrival. Magnification must then fall off as the strength of signal increases; it can be made to fall off slowly by providing the symmetrical and rectilinear condition described above, or rapidly to emphasise the limiter effect as described in section 7 below.

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* See No. 3 of the working instructions for a particular Kallirotron amplifier, Fig. 6 of this paper.

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4. SYMMETRICAL CIRCUITS.

The symmetrical case is of practical importance, and is specially easy to deal with theoretically. Putting

$$a_1 = a_2 = a$$
$$g_1 = g_2 = g$$
$$r_1 = r_2 = r$$
$$R_1 = R_2 = R$$

expressions (8) and (10) become

$$\rho_e = \rho - \left(\frac{g}{a}\right)^2 \cdot \frac{r^2}{\rho} \quad \ldots\ldots\ldots \quad (12)$$

where $\rho \equiv 1/a + r + R.$

$$m = \frac{g}{a} \cdot \frac{r + R}{\rho - \frac{g}{a} \cdot r} \quad \ldots\ldots\ldots \quad (13)$$

The value of m (when large) can be significantly expressed in terms of the ratio between the external anode-circuit resistance $(r + R)$ and the effective resistance ρ_e. From (12) we have

$$\rho_e = \frac{1}{\rho}\left(\rho + \frac{g}{a} \cdot r\right)\left(\rho - \frac{g}{a} \cdot r\right)$$
$$= 2\left(\rho - \frac{g}{a} \cdot r\right) \quad \text{approx.}$$

$$\therefore \quad m = 2\frac{g}{a} \cdot \frac{r + R}{\rho_e} \quad \ldots\ldots \text{ from (13)} \quad \ldots\ldots \quad (14)$$

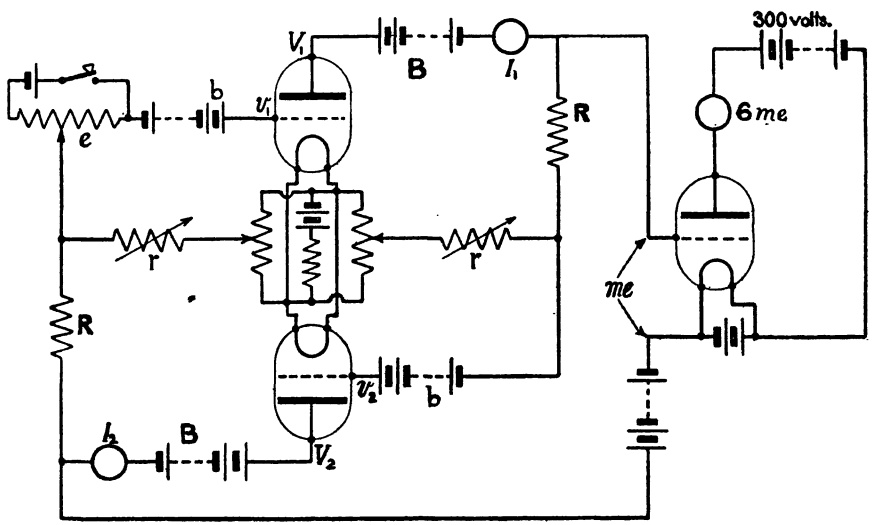

FIG. 3.

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Thus, for example, if it were feasible to keep the effective resistance of the whole anode circuit at 1 per cent. of its part $(r + R)$, we should have a magnification 200 g/a. With the pattern of triode of Fig. 2, this would be about 1,600.

5. EXPERIMENTAL RESULTS WITH KALLIROTRON AS AMPLIFIER.

The only Kallirotrons so far made up have been for low-frequency signals. This is the easiest form with which to experiment, since small stray capacities are innocuous, and the resistances may be ordinary wire bobbins wound non-inductively as for wire telegraphy. Stable magnifications up to 2,000 were obtained without difficulty. In order to measure the changes of P.D. between the anodes, a high-resistance voltmeter consisting of a microammeter with a few megohms in series was sometimes used. But a more convenient arrangement is shown in Fig. 3, where the P.D. between the two anodes of the Kallirotron is applied to the grid-filament of a third triode, in whose anode circuit any convenient instrument may be inserted. In the tests quoted below, this instrument was a moving-coil voltmeter of 65,000 ohms reading to 500 volts. The change of voltmeter reading then indicated about six times the change of P.D. $(V_1 - V_2)$ between the Kallirotron anodes, and is shown as $6me$, where m is therefore the Kallirotron magnification.

In Table I below, three tests are fully quoted, to show the sort of values which may be worked with and the magnifications obtainable. The magnifications given are the highest which could be obtained with tolerable ease and certainty.

TABLE I.

Test.	Filmt. P.D. volts.	r ohms.	R ohms.	B volts.	b volts.	I_1 mA.	I_2 mA.	V_1 volts.	V_2 volts.	v_1 volts.	v_2 volts.	e volts.	$6me$ volts.	m
1	4·0	10,850	50,000	150	0	0·8	0·7	101	108	−4·5	−5·6	·002	25	2,000
2	3·5	11,040	50,000	150	0	0·8	0·7	101	108	−4·2	−5·3	·002	10	900
3	4·0	7,600	30,000	150	8	1·4	1·4	97	97	−2·2	−2·4	·002	20	1,700

The figures of Table I may be used roughly to check the theory set forth earlier in this paper. The triodes used were a pair whose characteristics were nearly identical and had been determined, and the approximate values of a and g have been computed from the curves. Expression (13) shows that

TABLE 2.

Test.	r ohms.	R ohms.	a mA/volt.	g mA/volt.	$1/(a + r + R)$ ohms.	$(g/a)r$ ohms.
1	10,850	50,000	0·030	0·25	94,000	90,000
2	11,040	50,000	0·0275	0·23	96,000	92,000
3	7,600	30,000	0·034	0·29	67,000	65,000

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instability should occur when

$$1/a + r + R = (g/a)r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

In Table 2 these quantities are tabulated for the tests shown in Table 1. The agreement between the last two columns is quite as close as could be expected from the rather rough computations of a and g, in which the errors might well be as much as 10 per cent.

Another experiment may be quoted for the benefit of those who feel difficulty in regarding the conception of negative resistance as anything but a fantastic mathematical artifice. In place of the resistances R_1 and R_2 were placed the two magnet bobbins of a post-office relay, re-wound with finer copper wire (S.W.G. 47). The time constant of the relay actuated directly from a battery was, of course, quite small—probably a fraction of 1/100 second. But when inserted in the anode circuits of the Kallirotron, the relay became more and more sluggish as the magnification was increased, and with large magnifications it would not respond quickly enough for even the slowest practicable hand-speed Morse signalling. The inductance L of the relay being constant, the time constant L/ρ_e became greater and greater as the negative resistance $(\rho - \rho_e)$ (section 2) was increased. The relay, at any rate, was able to appreciate the reality of the negative resistance.

A Kallirotron amplifier constructed after the principle of Fig. 3 is shown in the photographs, Figs. 4 and 5, and by the diagram of connections and instructions, Fig. 6.* The circuits only differ from those of Fig. 3 in that grid batteries are dispensed with, and that a small capacity is bridged across from grid to grid of the Kallirotron combination for the purpose of preventing the occurrence of high-frequency oscillations determined by the accidental inductances of connections between grids and anodes and the other portions of the circuits. The resistances are bifilar bobbins of the form used in ordinary telegraphy. Their self-capacity provides the only limit of frequency (viz. an upper limit) for which the instrument is suitable. It can be used for currents of Morse signalling frequency, the output circuit being then (presumably) an electromagnetic telegraph relay; or for currents of low acoustic frequency, the output circuit being a telephone or any galvanometer or recording instrument; or even for speech frequencies. It is, in fact, a remarkably powerful telephone amplifier, although the efficiency as such is believed to be far short of what it would be if the resistances were wound for low self-capacity as is customary in telephonic work.

With this instrument it is possible to operate a Post Office "B" relay (re-wound with finer wire) with a signal of no more than $\pm$ 1 millivolt—*i.e.*, much less than the weakest signal encountered in submarine telegraphy; and of course it faithfully reproduces a quasi-permanent signal (*e.g.*, a prolonged spacing current in double-current Morse work), which no transformer or condenser circuit can do. As a telephone amplifier, if A. speaks in an ordinary conversational voice 10 or 20 feet from an ordinary pair of

* This instrument was designed and constructed at the Signals Experimental Establishment, Woolwich. I am indebted to Lieut.-Colonel Cusins, C.M.G., R.E., for permission to reproduce the photographs.

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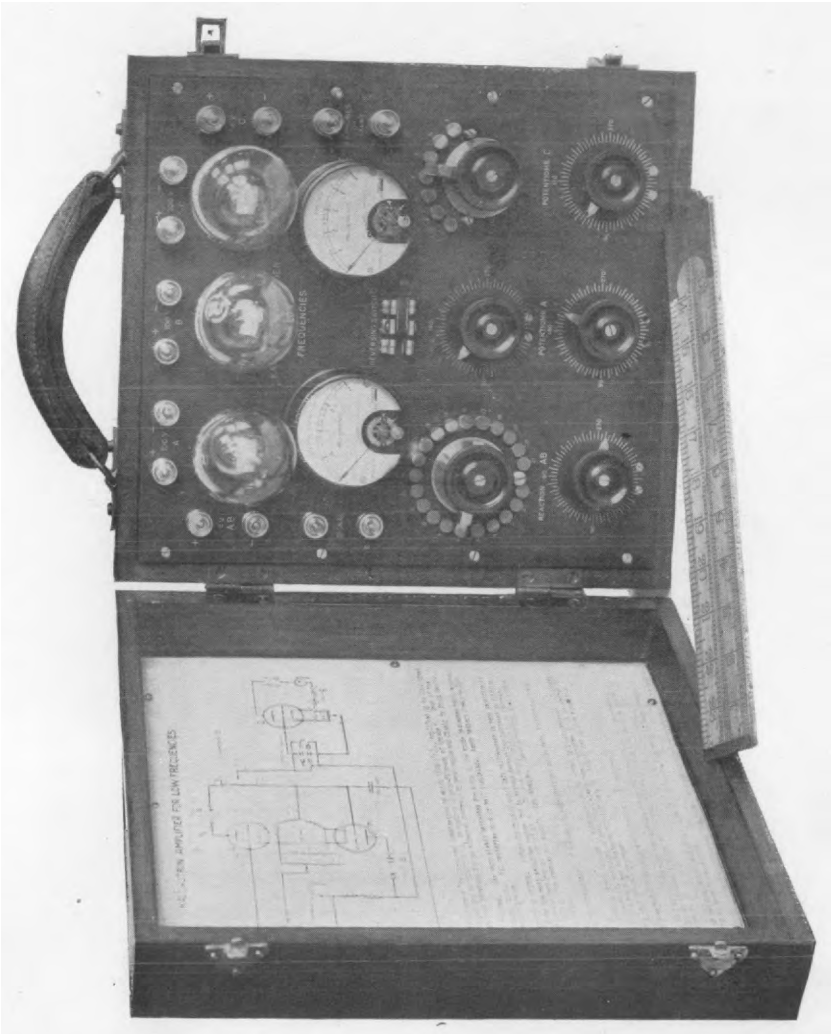

FIG. 4.—THE KALLIROTRON, GENERAL VIEW.

(*To face p.* 324.)

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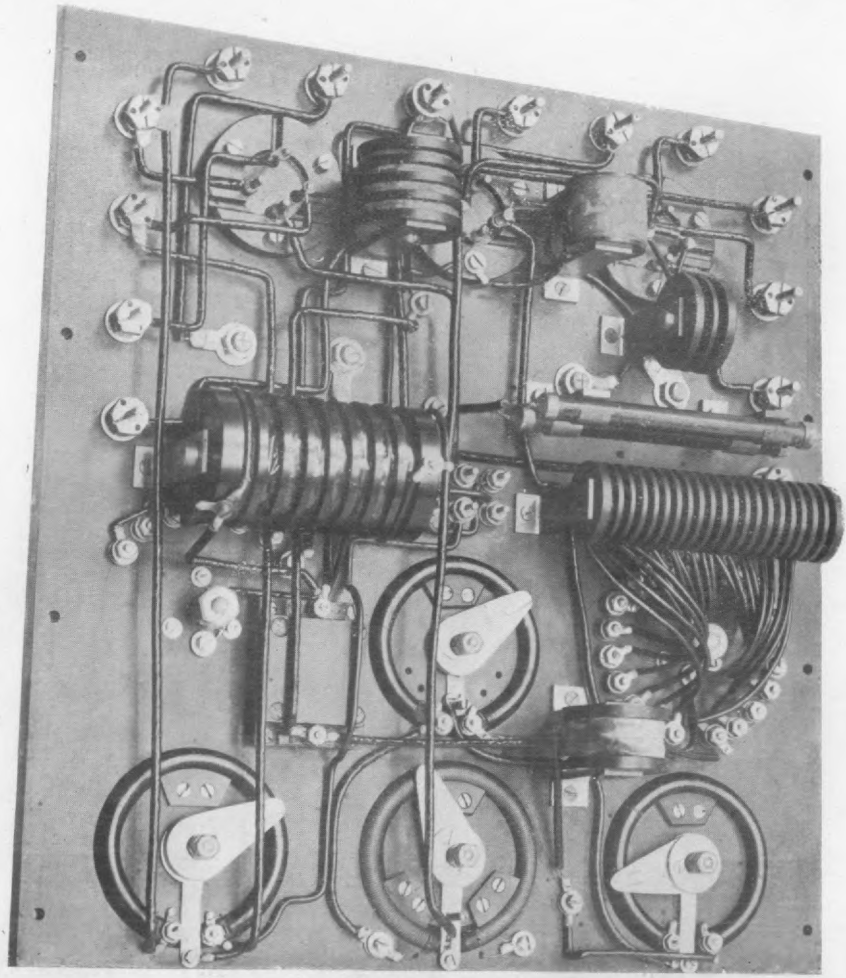

FIG. 5.—THE KALLIROTRON INSIDE VIEW

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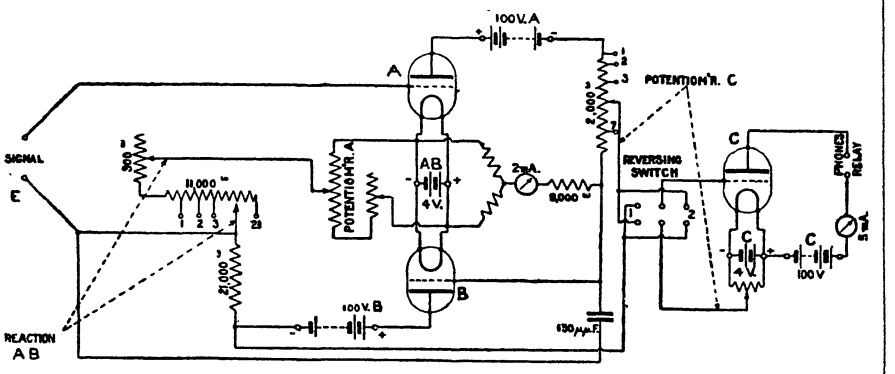

1. Circuits AB are a "Kallirotron" combination by which signal P.D., amplified up to 2,000 times according to setting of reaction AB, is applied to grid-filament of triode C. Each of the three adjustments provided for is effected coarsely by rear handle and finely by front handle.
2. Use "R" triodes. Use very steady batteries for A and B, the anode batteries being approximately equal and roughly 100 V. All batteries must be well insulated. Anode battery C may be 100 V. or any convenient value.
3. Open reversing switch. Adjust reaction AB until left milliammeter is very sensitive to potentiometer A in the most sensitive region; but is without instability indicated by flicking of milliammeter and backlash on potentiometer A. The more nearly reaction AB is increased towards instability, the greater the amplification obtained. Leave potentiometer A at middle of sensitive region.
4. If, owing to dissimilarity of triodes AB, adjustment cannot be made, interchange these triodes.
5. Close reversing switch to 1 or 2, whichever does not affect left milliammeter. In order that C may not upset AB, potential of grid C must always remain negative; it is determined by switch positions 1 and 2 and adjustment of potentiometer C. Adjust last to give about 1 mA. (if 100 V. used) in right milliammeter.
6. Slightly re-adjust potentiometer A and potentiometer C if necessary.
7. Signals of 1 mV. or less will then produce changes of current (right milliammeter) in phones or relay up to about $\frac{1}{2}$ mA. per mV. Earthy part of signal circuit should be joined to terminal marked E.
8. Beware of bad insulation, and of batteries AB changing voltage owing to large changes of temperature or to becoming exhausted.

FIG. 6.

high-resistance headgear telephones lying on a table and connected to the input terminals of the instrument in another room, B. hears loud speech in another pair of phones connected across the output terminals.

6. KALLIROTRON AS TELEPHONE AMPLIFIER.

The Kallirotron as a very sensitive amplifier for speech currents is of considerable interest; for in telephony there must be approximately equal amplification over a very wide range of frequencies (such as 200 to 4,000 periods per second), and low-decrement oscillatory circuits of the telephonic frequencies must not be used. Either of these conditions alone rules out the periodic form of retroactive amplifier. In the Kallirotron, the amount

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of amplification is independent of frequency, and there are no oscillatory circuits.

7. KALLIROTRON AS LIMITER-AMPLIFIER.

We have seen in section 3 that if

$$r + R >> 1/a,$$

the mean value of m is only slightly affected by the strength of the signal e. Conversely, to get a powerful limiter effect, we should make

$$r + R << 1/a.$$

This is most fully accomplished by making $R_1 = R_2 = 0$, as in Fig. 7.

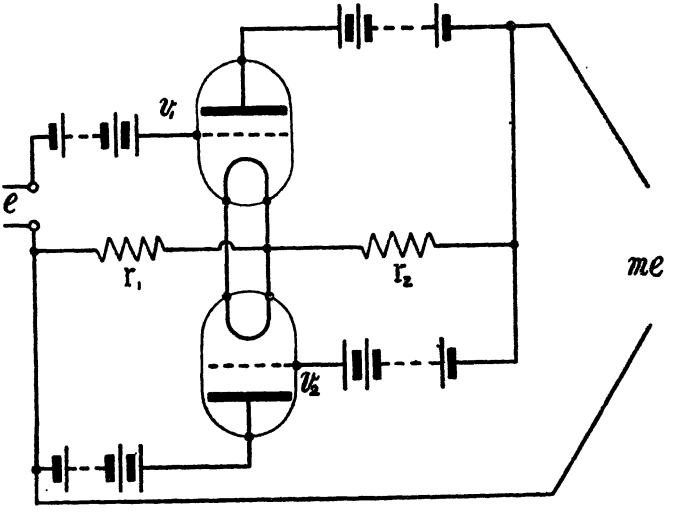

FIG. 7.

Expression (10) then becomes approximately

$$m = \frac{\frac{g_1}{a_1} \cdot r_1 \left(\frac{1}{a_2} + r_2\right) + \frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot r_1 r_2}{\left(\frac{1}{a_1} + r_1\right)\left(\frac{1}{a_2} + r_2\right) - \frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot r_1 r_2} \quad \ldots\ldots \quad (16)$$

As a close enough approximation for our present purpose, let us simplify the algebra by taking

$$r_1 << 1/a_1$$
$$r_2 << 1/a_2.$$

We may then write in place of (16)

$$m = \frac{\frac{g_1 r_1}{a_1}\left(\frac{1}{a_2} + \frac{g_2}{a_2} \cdot r_2\right)}{\frac{1}{a_1 a_2} - \frac{g_1}{a_1} \cdot \frac{g_2}{a_2} \cdot r_1 r_2} \quad \ldots\ldots\ldots \quad (17)$$

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In this expression, provided that m is large, the change produced by the signal is substantially confined to the first term of the denominator; and the more rapidly $1/(a_1 . a_2)$ increases, the more rapidly does m decrease, as the signal e increases.

Now an examination of the enlarged foot of an I, v characteristic such as that in Fig. 2 shows that over a suitable portion of the curve (*e.g.*, around $v = -8$ volts in the case of Fig. 2) g, and therefore also a, is approximately doubled by a 1-volt increase of grid potential. Let us then write

$$a_1 = \alpha_1 (1 + e)$$
$$a_2 = \alpha_2 (1 - e),$$

where α_1, α_2 are the values of a_1, a_2 with indefinitely weak signals. Then

$$\frac{1}{a_1 a_2} = \frac{1}{\alpha_1 \alpha_2 (1 - e^2)}$$
$$= \frac{1 + e^2}{\alpha_1 \alpha_2} \text{ approx. if } e^2 << 1.$$

Hence from (16)

$$m = \frac{\frac{g_1 r_1}{a_1} \left(\frac{1}{a_2} + \frac{g_2}{a_2} . r_2 \right)}{\left(\frac{1}{\alpha_1 \alpha_2} - \frac{g_1}{a_1} . \frac{g_2}{a_2} . r_1 r_2 \right) + \frac{e^2}{\alpha_1 \alpha_2}}$$

$$\therefore \quad \frac{1}{m} = \frac{1}{\mu} + \frac{e^2}{g_1 r_1 (1 + g_2 r_2)} \qquad \ldots\ldots\ldots\ldots (18)$$

where μ is the value of m with indefinitely weak signals.

The significance of (18) is best seen from a numerical example. For simplicity we will take the symmetrical arrangement. Suppose $V_1 = V_2 = 85$ volts, $v_1 = v_2 = -8$ volts; then approximately $g_1 = g_2 = 0{\cdot}08$ mA./volt $= 8 \times 10^{-5}$ mho, and $a_1 = a_2 = 1 \times 10^{-5}$ mho. The approximate values of $r_1 = r_2 = r$ are calculable from (15), putting $R = 0$; thus

$$\frac{1}{10^{-5}} + r = 8r$$

$$\therefore \quad r = \frac{10^5}{7} \text{ ohms.}$$

With these numerical values (18) becomes

$$\frac{1}{m} = \frac{1}{\mu} + \frac{e^2}{\frac{8}{7}\left(1 + \frac{8}{7}\right)}$$

$$= \frac{1}{\mu} + \frac{e^2}{2{\cdot}4}$$

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Hence output is

$$me = \frac{2{\cdot}4\,\mu e}{2{\cdot}4 + \mu e^2}.$$

This quantity increases as e increases; passes through a maximum value when $e = \sqrt{\frac{2{\cdot}4}{\mu}}$; and falls asymptotically to zero. In Table 3 the values of the output me are tabulated against values of the input e between 0 and 1 volt, for the two zero-signal magnifications μ of 1,000 and 100.

TABLE 3.

Input volts.	Output volts.	
	$\mu = 1{,}000$	$\mu = 100$
Zero.	Zero.	Zero.
0·0001	0·10	0·01
0·001	1·0	0·10
0·01	9·6	1·0
0·049	24·0 (max.)	—
0·1	19·4	7·1
0·155	—	7·7 (max.)
1·0	2·4	2·4

The table shows that we have produced a limiter-amplifier in which, when the signal reaches 0·049 (or 0·155) volt, any increase of strength actually reduces the output. Thus if this limiter-amplifier were applied to an antenna (nearly aperiodic or slightly mistuned to the signal) receiving a continuous-wave signal of something (say) between 1 and 10 millivolts, it should be possible, with proper precautions, by the ordinary tuning processes applied after the limiter, to select the desired signal and reject atmospherics and spark signals however strong.

Owing to the difficulty of devising suitable finely adjustable resistances for high-frequency currents, a good deal of experimental work is likely to be necessary before a satisfactory Kallirotron for wireless signals is constructed; but the urgent need of an effective limiter, as providing one method—probably the simplest—of overcoming jamming, seems to make the attempt well worth while. It may be convenient to use thermionic circuits (of independent thermionic tubes) as the resistances r_1, r_2.

8. KALLIROTRON AS OSCILLATOR.

Any negative-resistance device can obviously be used to produce sustained oscillation. One simple arrangement is that shown in Fig. 8, where the circuit LC begins to oscillate with approximately its own independent

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frequency as soon as the retroaction has been increased sufficiently to reduce the resistance of its anode circuit below zero. Where such an oscillator is

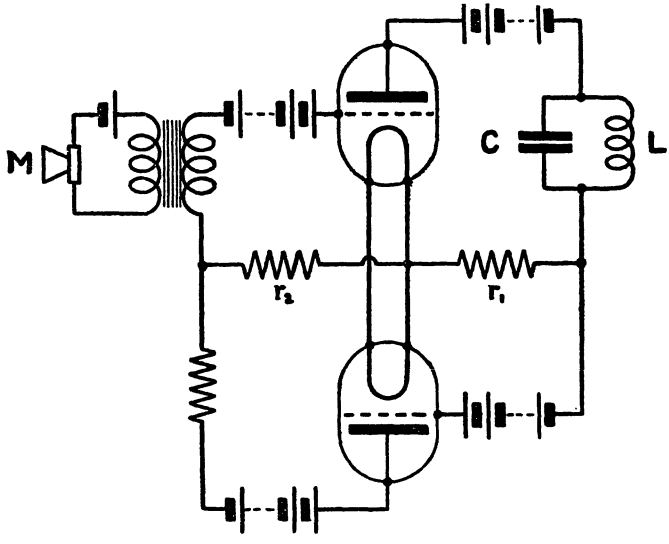

FIG. 8.

to be used for wireless telephony, speech control can be effected by a microphone M and transformer, the secondary of the latter being conveniently inserted between either grid and its resistance r.

Damped Oscillations in Coupled Circuits.

By G. BRAMWELL EHRENBORG.

(*Continued from page 224.*)

It will appear in what follows that α, β, p and q are the most important of the constants which occur in equations (9), and in Figs. 1 to 4 a graphical representation has been given of the ratios $\frac{\alpha}{p}$ and $\frac{\beta}{q}$ for various values of $\frac{R_1C_1}{R_2C_2}$ and of k. Each curve has been calculated on the supposition that R_1C_1, R_2C_2 and u_2 are kept constant and that u_1 alone varies. The quantity a which appears in the scale of ordinates is the ratio $\frac{R_2C_2}{\sqrt{u_2}}$. It is known that if circuit 1 is removed altogether, so that circuit 2 oscillates by itself, the logarithmic decrement per semi-period of these oscillations is $\frac{\pi}{2}\frac{R_2C_2}{\sqrt{u_2}}$,

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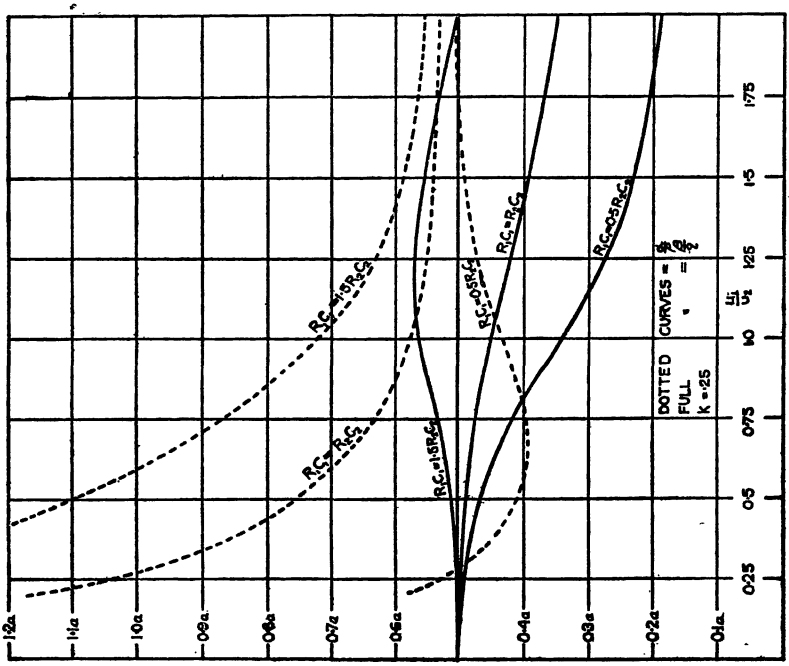

FIG. 1.

FIG. 2.

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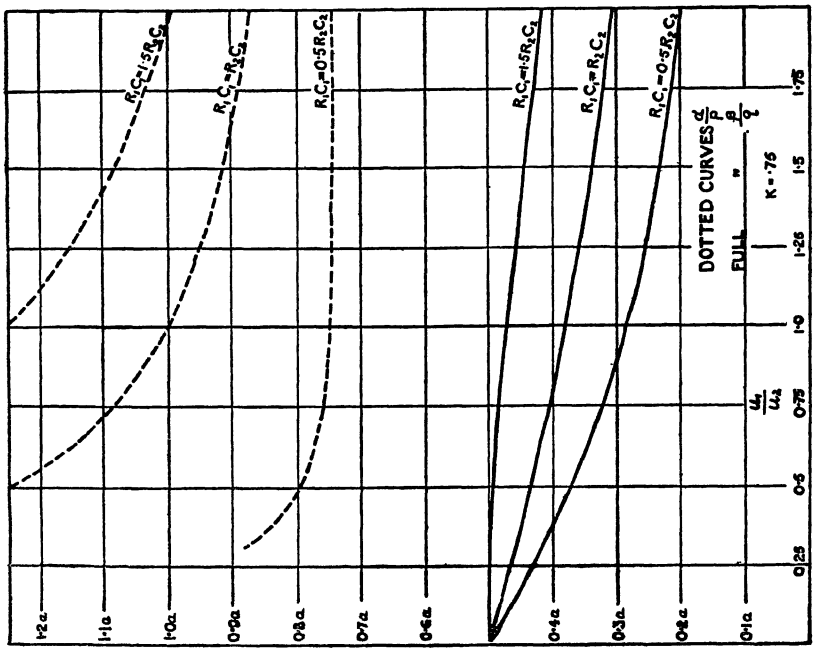

FIG. 4.

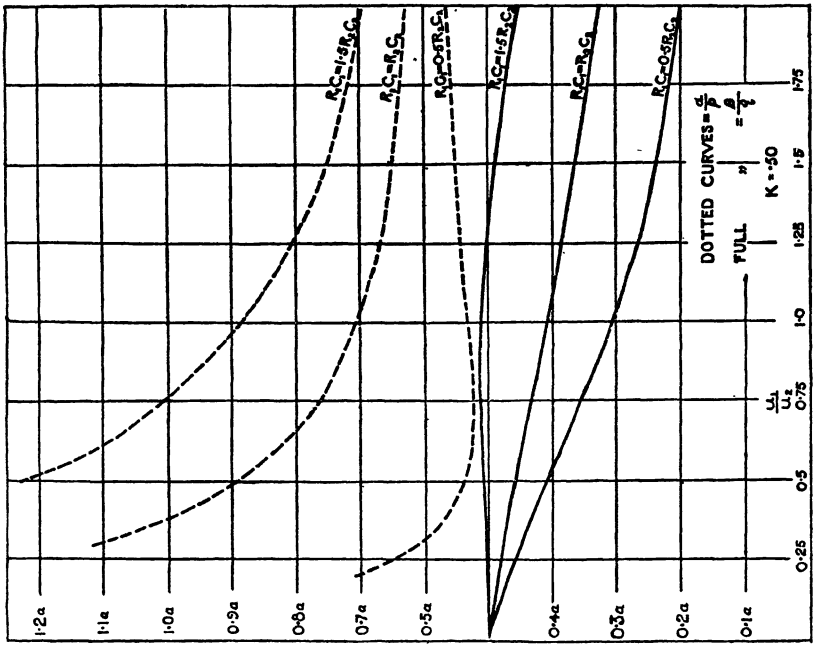

FIG. 3.

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so that $a = \frac{2}{\pi} \times$ logarithmic decrement in circuit 2 when isolated. As in practice one rarely encounters logarithmic decrements greater than 25 per cent., a will seldom exceed 0·16.

When $R_1C_1 = R_2C_2$ we see by (12) that $\frac{a}{p} = \frac{R_2C_2}{2}p$; hence, if we give the value $\frac{2}{\sqrt{u_2}}$ to a, we see that the curve showing $\frac{a}{p}$ when $R_1C_1 = R_2C_2$ may be used as a representation of p. Accordingly the numerical values of all the constants α, β, p, q can be found from the curves in question.

We now have to integrate equations (9). If D stands for the operator $\frac{d}{dt}$, and if we operate on the first equation with $D^2 + 2\beta D + q^2$ and on the second with fD and then subtract, the result will be in symbolical form

$$\{(D^2 + 2\alpha D + p^2)(D^2 + 2\beta D + q^2) - fgD^2\}\, x = 0 \quad . \quad . \quad (13)$$

We have $fg = \dfrac{\left(u_1 - \frac{1}{p^2}\right)\left(\frac{1}{q^2} - u_1\right)}{\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^2}(R_1C_1 - R_2C_2)^2\, p^2q^2$, and by applying equations (5) this easily reduces to

$$fg = \frac{k^2}{1 - k^2} \frac{(R_1C_1 - R_2C_2)^2}{\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

On account of the presence of the factor $(R_1C_1 - R_2C_2)^2$ this is quite a small quantity, so as a first approximation we may take as particular solutions of (13) the quantities $\epsilon^{(-\alpha t + it\sqrt{p^2 - \alpha^2})}$, $\epsilon^{(-\alpha t - it\sqrt{p^2 - \alpha^2})}$, $\epsilon^{(-\beta t + it\sqrt{q^2 - \beta^2})}$, and $\epsilon^{(-\beta t - it\sqrt{q^2 - \beta^2})}$. Before going any further it is necessary to examine how these solutions are affected when fg is taken into consideration. We will suppose that the effect of this is to change the first solution to $\epsilon^{\{-(\alpha + \Delta\alpha)t + it\sqrt{(p + \Delta p)^2 - (\alpha + \Delta\alpha)^2}\}}$. We will assume that Δp and $\Delta\alpha$ are so small that their squares and product may be neglected, an assumption that will be justified when we have found the actual values. On this assumption we find

$$\sqrt{(p + \Delta p)^2 - (\alpha + \Delta\alpha)^2} = \sqrt{p^2 - \alpha^2} + \frac{p\,\Delta p - \alpha\,\Delta\alpha}{\sqrt{p^2 - \alpha^2}},$$

so that the second approximation to the solution is

$$\epsilon^{\{-\alpha + i\sqrt{p^2 - \alpha^2} - \Delta\alpha + i(p\,\Delta p - \alpha\,\Delta\alpha)/\sqrt{p^2 - \alpha^2}\}t}$$

By substituting this quantity for x in (13) we can determine the values of Δp and $\Delta\alpha$. If we neglect $2fg\left(-\alpha + i\sqrt{p^2 - \alpha^2}\right)\left(-\Delta\alpha + i\frac{p\,\Delta p - \alpha\,\Delta\alpha}{\sqrt{p^2 - \alpha^2}}\right)$

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in comparison with $fg(-\alpha+i\sqrt{p^2-\alpha^2})^2$ and if we notice that $(-\alpha+i\sqrt{p^2-\alpha^2})^2+2\alpha(-\alpha+i\sqrt{p^2-\alpha^2})+p^2=0$, we get as the result of the substitution

$$\left[2i\sqrt{p^2-\alpha^2}\left\{\left(-\alpha+i\sqrt{p^2-\alpha^2}\right)^2+2\beta\left(-\alpha+i\sqrt{p^2-\alpha^2}\right)+q^2\right\}\times\right.$$
$$\left.\left(-\Delta\alpha+i\frac{p\,\Delta p-\alpha\,\Delta\alpha}{\sqrt{p^2-\alpha^2}}\right)-fg(-\alpha+i\sqrt{p^2-\alpha^2})^2\right]\times$$
$$\epsilon\left\{-\alpha+i\sqrt{p^2-\alpha^2}-\Delta\alpha+i(p\,\Delta p-\alpha\,\Delta\alpha)/\sqrt{p^2-\alpha^2}\right\}t=0.$$

If this equation is to be satisfied, the real and imaginary parts of the expression inside the square brackets must be separately equal to zero, so we find

$$\{(p^2-q^2)-4\alpha(\alpha-\beta)\}\,\Delta\alpha+2p(\alpha-\beta)\,\Delta p=-fg\alpha$$
$$\{4(p^2-2\alpha^2)(\alpha-\beta)+2\alpha(p^2-q^2)\}\,\Delta\alpha-\{2p(p^2-q^2)-4\alpha p(\alpha-\beta)\}\,\Delta p=fg(p^2-2\alpha^2).$$

It is quite sufficient for us to know the order of magnitude of $\Delta\alpha$ and Δp, accurate values not being required, so we will neglect α^2 and β^2 in comparison with p^2 and q^2; the above equations then become

$$(p^2-q^2)\,\Delta\alpha+2p(\alpha-\beta)\,\Delta p=-fg\alpha$$
$$\left\{\frac{\alpha}{p}(p^2-q^2)+2p(\alpha-\beta)\right\}\Delta\alpha-(p^2-q^2)\,\Delta p=+\frac{1}{2}fgp$$

of which the approximate solutions are

$$\left.\begin{aligned}\Delta\alpha&=\frac{fg}{(p^2-q^2)^2}(\alpha q^2-\beta p^2)=-\frac{k^2u_1u_2(R_1C_1-R_2C_2)^3}{2\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^5}(u_1-u_2)\\ \Delta p&=-\frac{fg}{2(p^2-q^2)}p=-\frac{k^2u_1u_2(R_1C_1-R_2C_2)^2}{2\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^3}p\end{aligned}\right\}\quad(15)$$

If we investigate the solution $x=\epsilon^{(-\alpha t-it\sqrt{p^2-\alpha^2})}$ the same values of $\Delta\alpha$ and Δp will be arrived at, and in the case of the two remaining solutions the corresponding quantities are

$$\left.\begin{aligned}\Delta\beta&=-\frac{fg}{(p^2-q^2)^2}(\alpha q^2-\beta p^2)=+\frac{k^2u_1u_2(R_1C_1-R_2C_2)^3}{2\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^5}(u_1-u_2)\\ \Delta q&=+\frac{fg}{2(p^2-q^2)}q=+\frac{k^2u_1u_2(R_1C_1-R_2C_2)^2}{2\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^3}q\end{aligned}\right\}\quad(16)$$

We notice that $\Delta\alpha=-\Delta\beta$ and $\frac{\Delta p}{p}=-\frac{\Delta q}{q}$.

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The numerical values of $\frac{\Delta q}{q}$ are exhibited in Fig. 5, where the constant a has the same meaning as in Figs. 1 to 4. It is seen that when $R_1C_1 = 0{\cdot}5\,R_2C_2$ (or $1{\cdot}5\,R_2C_2$), $\frac{\Delta q}{q} = 0{\cdot}004$ if $k = 0{\cdot}10$ and $a = 0{\cdot}16$, so under these circumstances Δq (and Δp) can evidently be neglected. As the writer has no

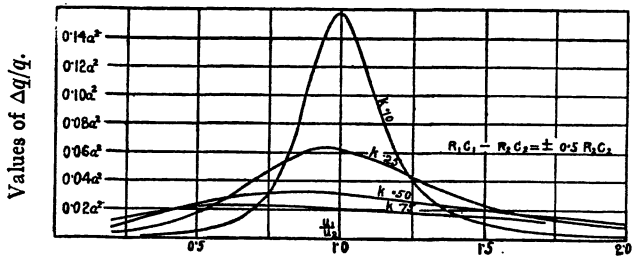

FIG. 5.

numerical data which would enable him to say what values of the ratio $\frac{R_1C_1}{R_2C_2}$ are likely to be encountered in practice, he has chosen the values 0·5 and 1·5 in a purely arbitrary manner for the purpose of calculating curves in connection with this paper. It is, however, a simple matter to modify the curves from the formulæ when other values of the ratio have to be considered.

The logarithmic decrement per semi-period of $\epsilon^{(-\alpha t + it\sqrt{p^2-\alpha^2})}$ is $\frac{\pi\alpha}{\sqrt{p^2-\alpha^2}} = \pi\frac{\alpha}{p}\frac{1}{\sqrt{1-\alpha^2/p^2}}$, so it is of importance to know what $\frac{\alpha}{p}$ becomes in the second approximation. It evidently takes the form

$$\frac{\alpha+\Delta\alpha}{p+\Delta p} = \frac{\alpha}{p} + \frac{\Delta\alpha}{p} - \frac{\alpha}{p}\frac{\Delta p}{p} = \frac{\alpha}{p} - \left(\frac{\alpha}{p} - \frac{(R_1C_1 - R_2C_2)(u_1-u_2)}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\right)\frac{\Delta p}{p}.$$

Similarly, $$\frac{\beta+\Delta\beta}{q+\Delta q} = \frac{\beta}{q} - \left(\frac{\beta}{q} - \frac{(R_1C_1 - R_2C_2)(u_1-u_2)}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\right)\frac{\Delta q}{q}.$$

The expressions $\frac{(R_1C_1 - R_2C_2)(u_1-u_2)}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}$ and $\frac{R_1C_1 - R_2C_2)(u_1-u_2)}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}$ which we shall call $\tan\theta$ and $\tan\phi$ respectively, in anticipation of the final results, where θ and ϕ appear as integration constants, are shown graphically in Fig. 6. On referring to Figs. 1—4 we see that $\tan\theta$, $\tan\phi$, $\frac{\alpha}{p}$ and $\frac{\beta}{q}$ are all of the same order of magnitude, so if we can neglect Δp and Δq in comparison with p and q, we are equally justified in neglecting $\Delta\alpha$ and $\Delta\beta$ in comparison with α and β. It is evidently fairly safe to assert that if k is not

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less than 0·1 it is unnecessary to proceed to the second approximation, and that when integrating equations (9) we may neglect the product fg. On the other hand the maxima of the quantities in Figs. 5 and 6 grow very rapidly as k diminishes, so it is clearly necessary to proceed with caution when k is less than 0·1, unless $R_1C_1 - R_2C_2$ is small.

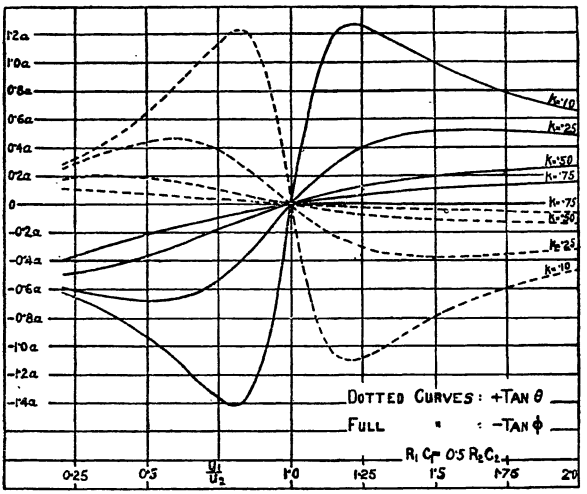

FIG. 6.

There is a further reason to exercise care when the coupling is very loose. From Figs. 1 to 4 we find that the variation in the values of $\frac{\alpha}{p}$ and $\frac{\beta}{q}$ when u_1 is nearly equal to u_2 becomes more and more rapid as k diminishes. The variation is due to the presence of the factor $\frac{u_1 - u_2}{\frac{1}{q^2} - \frac{1}{p^2}}$ in the second terms of $\frac{\alpha}{p}$ and $\frac{\beta}{q}$. (See equations (12).) By (6) this factor, which we shall call Z, may be expressed in the form $\frac{X}{\sqrt{X^2 + Y^2}}$, where $X = \frac{u_1 - u_2}{\sqrt{u_1 u_2}}$ and $Y = 2k$. If X, Y, Z, are looked upon as rectangular co-ordinates, Z may be represented graphically by the surface $Z = \frac{X}{\sqrt{X^2 + Y^2}}$. Now transform to cylindrical co-ordinates, *i.e.* $X = \rho \cos \phi$, $Y = \rho \sin \phi$, $Z = Z$; then we have $Z = \cos \phi$. A little consideration will show that the surface is generated by the motion of a straight line which intersects the axis of Z perpendicularly and rotates round it, rising and falling as it rotates in such a way that its height above the XY plane is equal to $\cos \phi$. The surface can easily be visualised if one looks upon it as a spiral staircase where the height of the steps is not constant;

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in fact, for the first half of a complete circuit round the central pillar the staircase leads downwards, and then upwards during the second half. The point that should be grasped is that near the axis of Z the slope of the surface is very steep. Suppose that we are experimenting with two circuits which are very loosely coupled; suppose further that we have adjusted u_1 to be almost equal to u_2 but slightly less. From any one of a number of causes u_1 may now alter slightly so as to exceed u_2, and owing to the steep slope of the surface this is enough to change Z from -1 to $+1$, nearly. Hence, unless $R_1C_1 = R_2C_2$, the values of $\frac{\alpha}{p}$ and $\frac{\beta}{q}$ are practically speaking indeterminate under the circumstances considered.

This indeterminateness of $\frac{\alpha}{p}$ and $\frac{\beta}{q}$ for small values of k is a question of considerable practical importance, as is also the fact that $\Delta\alpha$, Δp, etc., increase very quickly as k decreases, for when making measurements with decremeters and cymometers one usually works with very weak couplings. As the readings taken on such instruments are not in general themselves the quantities one seeks to discover, but are intermediary quantities which have to be interpreted by formulæ derived from theory, it is doubly necessary to arrange that $R_1C_1 = R_2C_2$ if consistent results are desired.

(To be concluded.)

The Production of a Single Frequency in Spark Transmitters.

By THE EDITOR.

From time to time methods are described and patents are taken out for the production of a single frequency in the aerial of a spark transmitter. When an aerial is coupled to a tuned oscillatory circuit containing an ordinary open spark-gap, the coupling cannot exceed a certain small value without causing the aerial to radiate waves of two different frequencies. This way of describing the effect is based upon the result of mathematical analysis. If one could actually see the current in the antenna or the waves being radiated one would certainly describe the phenomenon in a different manner; they would see an alternating current of one definite frequency but with a variable amplitude. Up to a certain value of the coupling these surges or beats in the amplitude of the aerial current do not appear; below this value of the coupling the amplitude grows to a maximum and then gradually decreases to zero. If the coupling is increased, energy is transferred more rapidly to the aerial with the result that the transfer is complete before the damping due to radiation and various losses has sufficiently reduced the amplitude of the current to prevent the E.M.F. induced by it in the primary circuit maintaining the spark. The energy is then transferred back from the aerial to the primary circuit, and so on until the amplitude is sufficiently reduced to allow the spark to be extinguished. As Max Wien first clearly showed, a gap of the

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Lepel type has such a pronounced tendency to extinction that the coupling can be considerably increased without causing this surging backward and forward of the energy.

As was stated above methods are continually being devised for giving a single frequency in the aerial whilst using an ordinary spark-gap. Let us examine this claim a little more closely. The ordinary coupled aerial gives a single frequency if the coupling is suitably adjusted. In what then does the advantage of the proposed methods consist? Although not always explicitly stated, it is implied that the proposed arrangements allow of a closer coupling without introducing beats. If this is not so, it is difficult to see their *raison d'être*. In some cases it is definitely stated that the method allows of closer coupling. This was so in the system "*à onde unique*" which we showed to be based on a fallacious method of calculating the coupling.

The only safe and reasonable measure of the coupling is the rate at which energy is transferred from one circuit to the other and—excluding quenching effects due to special types of spark-gaps—this rate of energy transfer is a measure of the frequency of the surges or beats. If the coupling is really closer, the energy will be transferred more rapidly backward and forward between the spark-gap circuit and the aerial, and the greater will be the divergence between the component frequencies.

It would appear then that, apart from improvements in the spark-gap, closer coupling while maintaining a single frequency is a contradiction in terms.

In a paper published in *The Electrician* of August 6th, 1915, we showed that the two frequencies occurring in the solution of the equations of two coupled oscillatory circuits could be merged into a single frequency for a definite value of the coupling. If the circuits have no damping two frequencies are always present except for zero coupling, but actual circuits always have damping and it was shown that the coupling can therefore have a certain small but definite value without introducing two frequencies. That is to say, that apart from the initial building-up period the oscillation can be regarded as a damped sine-wave of one frequency.

It may have been noticed, however, that some of the proposed systems employ a combination of magnetic and electric coupling, *i.e.* energy is transferred both by coils and condensers. In these systems the aerial is partly precharged. Now in a precharged aerial, *e.g.* Marconi's original plain aerial, when the gap breaks down, the damped oscillatory current in the aerial has its maximum amplitude at the initial moment, whereas in a coupled aerial, the amplitude is gradually built up from zero as the energy is transferred from the primary circuit. By combining these two processes it is possible to precharge the aerial to a certain degree and then to supply energy to it by magnetic coupling at a rate sufficient to compensate for the decrease in amplitude which would ordinarily take place in a simple precharged aerial. In this way the amplitude could be maintained at its initial value for a considerable time. This appears to be the idea underlying some of the suggested arrangements, but one must not overlook the fact that they involve precharging the aerial, the disadvantages of which are well known.

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Duplex Wireless Telephony: Some Experiments on its Application to Aircraft.*

By Captain P. P. ECKERSLEY.

(1) INTRODUCTION.

This paper deals with experiments on duplex wireless telephony for aircraft carried out at the Wireless Experimental Establishment of the R.A.F.

With true duplex telephony sets the operator should be able to send and receive simultaneously, using the wireless telephone exactly as he uses the ordinary wire telephone. The chief problem of simultaneous reception and transmission is to protect the receiver from the powerful oscillations in the aerial when sending, without detriment to its sensitivity. To indicate the magnitude of the problem it may be noted that the standard aircraft transmitter deals with energies some million times greater than those dealt with by the receiver. The systems using a switch to change over from sending to receiving may be referred to as *switched wireless telephony* in contradistinction to *duplex-wireless telephony*. True duplex wireless telephony has great practical advantages over the switching method and by its use a subscriber to any ordinary telephone line could be put into communication with an aeroplane in flight or with a ship at sea.

A number of solutions of the problem have been suggested. For use on the ground two aerials, one for transmission and one for reception, may be employed, placed at right angles and spaced more than one-quarter wavelength apart. This is obviously not applicable to aircraft. Frames at right angles have also been suggested but it is questionable whether this would be very practical for aircraft.

Balancing systems with two aerials, one receiving and the other transmitting in which the effect of the transmitting aerial on the other is balanced against some equal and opposite effect purposely communicated through circuits under the operator's control, have given considerable success for ground work. This method is difficult of application to aircraft on account of varying antenna constants when non-rigid aerials are used. There is another general method of protecting the receiver in which the earth lead is split into two paths and it is arranged that all the transmitter currents pass through one path and all the received currents through the other.

To overcome the criticality of the balancing system a compromise is possible wherein the transmitter only oscillates when the operator is actually speaking. Such *quiescent aerial transmitters*, however, have to be rather complicated in order that they may transmit good speech, but by arranging them so that there is a small permanent oscillation in the antenna they give very much better articulation. This last type of transmitter has been given the name of *augmented oscillation transmitter* and when it is used with a partially protected receiver it constitutes a *partial duplex system.*

* Abstract of paper read before the Institution of Electrical Engineers (Wireless Section) on March 17th, 1920.

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(2) AUTOMATIC DUPLEX WIRELESS TELEPHONY SYSTEMS.

The quiescent aerial arrangement has little superiority as regards the user's point of view over the switching system, as it is still impossible for "chipping in" by the other station to be effected. The quiescent aerial transmitter was first proposed by the General Electric Company of America and later was developed independently by Major Whiddington. It is a direct outcome of the choke control system recently described by Major Prince.* Instead of modulating by the voice the intensity of a continuous source of power supplied to the oscillator as with choke control, power is only supplied when speaking. For this purpose the transmitting microphone is inductively coupled to the plate circuit of the oscillating valve so that the only source of voltage in that circuit is the E.M.F. derived from the secondary of the transformer influenced by the transmitting microphone. In an improved arrangement the microphone may control an amplifying valve, the plate circuit of which is used to feed the plate circuit of the oscillating valve. The arrangement is indicated in Fig. 1. In this diagram the microphone M controls the output of the valve V_1 through the grid circuit transformer T_1. The plate circuit of V_1 includes the primary winding of transformer T_2 and the high tension battery B_2. The only source of high tension current in the anode circuit of the main oscillating valve V_2 is the induced E.M.F. in the secondary winding of T_2. The quality of the radiated speech

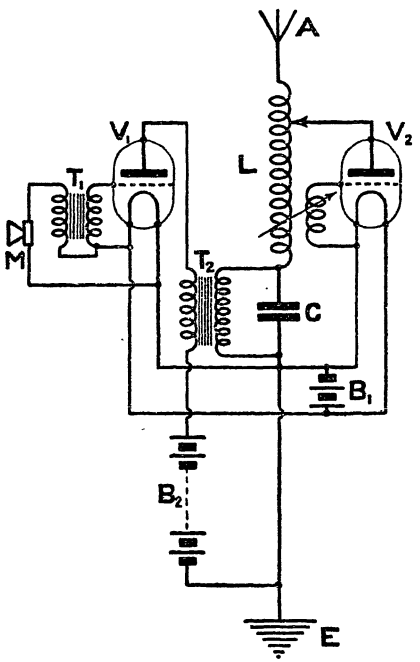

FIG. 1.

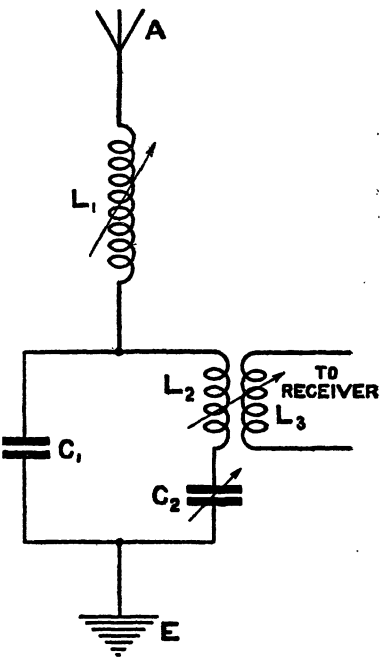

FIG. 2.

* See RADIO REVIEW, 1, pp. 281—283, March, 1920.

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was much worse on the whole than that given by transmitters using the choke control method. It lacked a certain mellow roundness, and was sometimes broken and peaky. It was found, however, that by the application of a small steady voltage in series with the secondary of the transformer T_2 (Fig. 1) of just sufficient value to keep the system oscillating feebly, the speech quality was at once changed from bad to good.

Various theories to account for this effect are set out in the paper.

An alternative arrangement was subsequently investigated by the author in which the grid of the oscillating valve was continually varied in potential from an outside source at a frequency corresponding to the natural period of the aerial circuit. This was achieved by coupling the grid circuit to a closed oscillating circuit tuned to the frequency of the aerial oscillations.

The general trend of these experiments was to show that the quiescent aerial system fails owing to the non-instantaneous response of the oscillating valve to the short high tension pulses applied to it—in other words, that the high frequency oscillation does not build up as soon as the H.T. voltage is applied, while it also persists for a short time after the voltage is removed. With all these arrangements it was also found difficult to prevent the receiver from picking up high and low frequency disturbances from the transmitter, while the latter was active. This resulted in deafening noises in the receiving telephones when speaking into the microphone, and it was therefore necessary to protect the receiver from such disturbances. When this is done it is no longer necessary to use a truly quiescent aerial transmitter and a truer duplex telephone system becomes possible.

(3) TRUE DUPLEX WIRELESS TELEPHONE SYSTEMS.

In these arrangements any type of transmitter may be employed that will ensure the production of good speech quality. The main problem of the arrangement was to ensure that the receiver was not suffering any great loss of sensitivity due to the presence of relatively large alternating currents generated by the transmitter.

The first suggested method embodied the use of two aerials separated by a few feet from one another and using different wavelengths for transmitting and receiving. At the receiver a rejector circuit was included to bye-pass the induced oscillations of the transmitter frequency and to provide a path for the proper received signals. The arrangement used is indicated in Fig. 2. The condenser C_1 provides a bye-path for the oscillations of the transmitter frequency and should have as large a capacity as possible consistent with sensitivity. Its value may be increased by the use of the series inductance L_1. The shunt circuit L_2 C_2 is tuned to the frequency of the received signals, and the receiver is coupled to this circuit by the loose coupling L_2 L_3. A safe value for C_1 is 0·003 mfd. Using an aerial of capacity 0·00025 mfd., C_2 can be made to vary between 0·0005 and 0·001 mfd., depending upon the wavelength, and L_2 may be adjusted to suit the wavelength. It is claimed that this circuit is an improvement upon the simple rejector circuit, and that it reduces the number of necessary adjustments. The circuit will work with a difference of 20 per cent. between the two wavelengths.

(To be concluded.)

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Wireless Telephony on Aeroplanes.

By Major C. E. PRINCE, O.B.E.

(*Continued from p.* 283.)

It was intended to replace the receiver of Fig. 2 which used only low frequency amplification, by one including high frequency magnifying stages, and for this purpose a five valve receiver was designed by Major Whiddington but it was not manufactured in sufficient quantities in time to play a large part in the war. As compared with the early three valve receiver however it was about ten times as sensitive for strong signals and thirty times for weak ones. It had two high frequency magnifications, and two low, and a detector valve.

The normal working range between machines with the apparatus that was generally in use was about four miles, though this was often very much exceeded. The range to a ground station was from twenty to fifty miles or more. A trailing aerial wire 120 feet in length was used in the transmitting machines with an aerial current of the order of 0·4 ampere.

When larger and more powerful ground stations were put up—as in the case of the home air raid defence stations—a machine could speak or be spoken to at distances of from 70 to 100 miles.

With the signing of the Armistice the Cologne postal service was equipped with these sets and some remarkable results were obtained. The Central Station on this route handled 5,000 messages during the five months that it was in operation.

At the conclusion of the paper a very brief outline was given of the most recent apparatus which the author is developing.

DISCUSSION.

Captain FURNIVAL referred briefly to the greater reliability obtained when using high-frequency magnification at the receiver than when using only detecting and low-frequency magnifying valves. In the construction of suitable transmitting microphones for use in aircraft a great deal was found to depend upon the material of the diaphragm as well as upon its thickness and size. Mica was found to give the best results but aluminium was also good.

Captain ROUND stated that the grid control modulation method becomes a type of choke control when the same valve is used both for generating the oscillations and for the modulation. The earlier circuit described in which the microphone was directly in series with the aerial circuit is a more useful one when larger powers are used, but, in that case, the microphone could not be directly inserted in the aerial circuit but must be arranged to influence it by a suitable coupling.

Mr. L. B. TURNER also dealt with the choke modulation control and outlined its mode of operation. He preferred to regard the choke more as maintaining constant the output current from the high-tension battery or generator, in place of the explanation given in the paper. Looking at the problem from this point of view, there should be no optimum value for the choke inductance as it would tend to maintain the current steadier the larger its value. When however the impedance of the choke coil at the frequency used becomes equal to the internal resistance of the oscillating valve, little advantage is gained by further increasing the inductance. In the example quoted in the paper in which an inductance of 5 henries was said to be required for a sound frequency of 750 per second, the impedance of such a coil at that frequency would be about 25,000 ohms. This is rather larger than but of the same order as

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the internal resistance of the valve. He also showed a diagram illustrating another suggested arrangement. In this case the microphone was inductively coupled to the plate circuit of a valve arranged to generate feeble oscillations only. The output from this feeble oscillator was amplified by a second valve, or by a bank of valves in parallel, and then transferred to the aerial circuit in the usual manner. Such an arrangement reduces the difficulty of two-way work.

It has been suggested that the unmodulated residuum of the radiation from the transmitter may have some useful effect at the receiver in stimulating the efficiency of the rectifier there used. Such an arrangement, however, is extremely inefficient, and it is much preferable to provide this steady component at the receiver itself rather than at the transmitter. The whole of the transmitted energy should then be modulated, or preferably matters should be so arranged that radiation only takes place when speech is being transmitted. At the receiver a local heterodyne may be used, tuned dead on to the incoming waves.

Major WHIDDINGTON. One fundamental feature of radiotelephony should not be forgotten in discussing any arrangement of transmitting or receiving circuits, and that is the change of wavelength which is inseparable to voice control of the radiation. If the modulated current is in the form of a uniform sine wave of frequency Q, the resultant output frequency which was originally P, varies between $P + Q$ and $P - Q$, hence it is impossible at the receiver to tune to all of the waves, and as a consequence the articulation becomes imperfect if strong reaction is used.

Captain P. P. ECKERSLEY stated that with the apparatus at present used in aircraft shorter wavelengths give better results than longer ones. It had been shown that 300 metres was preferable to 450 and therefore the wavelength fixed by the International Convention for use in aircraft, namely, 900 metres, was not at all a good one. It should be possible to find a more advantageous shorter wavelength which would be free from disturbances. With reference to the advantages and disadvantages of the choke control method it was surely better to so arrange the control that the modulation was both above and below the normal intensity of transmission instead of merely to modulate below the maximum. He thought that the quiescent aerial systems that had been mentioned by Major Whiddington did not give very good speech, and their only advantage was that one got rid of the changeover switch for changing from transmission to reception. With the choke control method, however, articulation was very good. The articulation obtained at the receiver was as much dependent upon the receiver as upon the transmitter. Breaking of the speech sometimes occurred even with the choke control method, but not so frequently as when grid control is used. The most serious problem in aircraft work was the elimination of magneto noises.

Major VINCENT-SMITH pointed out the enormous advantages of the remote control unit as applied to the apparatus described. One of the most important, in fact the most important, application of wireless telephony was to inter-machine work. The question of jamming of the wireless telephones was also an important one, but it was found that such jamming was never a very serious item on the Western Front.

Captain MCDOUGAL stated that the main early work was concerned with reducing the size, weight and number of adjustments of the instruments. With the soft valves that were at first used in these sets adjustments were extremely difficult in the air as it was sometimes necessary to warm the valves to obtain the best results. The variations of the wavelength caused by changes in the configuration of the trailing aerial had been overcome by the use of fixed frame aerials on the machines. Small wavelength variations might also be caused by variations in the high-tension voltage. Magneto noises were, however, rather worse on the frame aerials than on the trailing aerials.

A few remarks were also contributed by Major ORME, Mr. DOWSETT and Professor FORTESCUE.

Major PRINCE in reply stated that the whole subject of wireless telephony covered a very wide field and that he had not intended to deal with all the various problems connected with it, but merely its application to aircraft work. He had not intended to imply that there was a definite optimum value for the inductance of the choke coil, but merely that the results improved as the choke was increased up to a point, but after that there was very little further gain. As to the power loss in the control valve this could be reduced to a very small quantity under normal conditions, but as soon as the microphone is spoken to the control valve absorbs more power. He thought that the idea of choke control originated in America.

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Review of Radio Literature.

1. Articles and Patents.

269. FURTHER DISCUSSION ON "ELECTRIC OSCILLATIONS IN ANTENNAS AND INDUCTION COILS," BY J. M. MILLER. J. H. Morecroft. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 652—654, December, 1919.)

A further contribution to the discussion on the paper with the above title * pointing out that what the effective inductance and capacity of an antenna are when it is oscillating in its fundamental mode, is largely a matter of the view point. It is pointed out that the formulæ obtained for the capacity and inductance depend upon whether the electromagnetic or the electrostatic energy is considered first in deriving the formulæ. In the latter case the relations $L_e = 8L_0/\pi^2$ and $C_e = C_0/2$ would have been obtained, instead of the relations given in the original paper.

270. ON THE PHENOMENA PRODUCED BY THE INTERRUPTION OF A STEADY CURRENT IN AN OSCILLATORY CIRCUIT. G. Zickner. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 478—498, October, 1919.)

The theory of the oscillation produced by the cessation of a steady current through the inductance of an oscillatory circuit is discussed mathematically. Experimental observations in support of theory are given, including Braun tube oscillographs.

271. DIFFICULTIES IN THE TRANSMISSION AND RECEPTION OF SUSTAINED WAVES. M. Wien. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 442—451, October, 1919.)

A non-mathematical discussion of the following points: (*a*) difficulties in the production of oscillations, (*b*) alteration of wavelength, (*c*) difficulties in distinguishing between sending stations, (*d*) harmonics, (*e*) radiation from receiving antenna, (*f*) interference from spark stations, (*g*) production of anode voltage, (*h*) difficulties in manufacture of military C.W. sets.

272. THE CALCULATION OF THE SELF-INDUCTANCE OF RECTANGULAR FLAT COILS. A. Esau. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 386—394, September, 1919.)

The calculation follows the same lines as his previous paper on rectangular solenoidal coils.† It is not a current sheet method but sums up the effect of the separate turns. The result is given in the same form as before, viz., $L = 8\,a\,n\,(S_1 + S_2)$ where a is the mean radius and n the number of turns. Tables and curves are given for the constants S_1 and S_2 which are functions of n, a and the pitch of the turns.

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* See RADIO REVIEW Abstract No. 2, October, 1919.

† RADIO REVIEW Abstract No. 73.

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273. STRANDED OR SOLID WIRE? W. Rogowski. (*Archiv für Elektrotechnik*, 8, p. 269, 1919.)

A mathematical investigation of the conditions under which a coil wound with solid wire has a lower high-frequency resistance than if a stranded wire were used; also of the relation between the resistance and the number of wires in the stranded conductor.

274. SKIN EFFECT IN IRON. L. Truxa. (*Archiv für Elektrotechnik*, 8, pp. 137—144, August 28th, 1919.)

A theoretical investigation of the apparent resistance and equivalent permeability taking the hysteresis loss into account.

275. AN OSCILLATION SOURCE FOR RADIO RECEIVER INVESTIGATIONS. J. Weinberger and C. Dreher. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 584—602, December, 1919.)

Describes a triode generating source of sustained oscillations suitable for laboratory experiments in which it is necessary that stray electric and magnetic fields be reduced to a minimum. Multilayered coils are used to reduce the stray magnetic field and the whole apparatus is enclosed in copper or brass shields connected to one terminal of the filament battery. The source described provides an E.M.F. rather than a current thus simulating closely the effect of electric waves on an antenna.

276. APPARATUS FOR HIGH-FREQUENCY MEASUREMENTS E. Nesper and P. Floch. (*Physikalische Zeitschrift*, 20, pp. 371—375, August, 1919.)

An arrangement of vacuum tubes for a variety of H.F. measurements as well as for radio-transmission and reception.

277. OSCILLOGRAPHIC STUDY OF THERMIONIC GENERATORS. K. Mühlbrett. (*Archiv für Elektrotechnik*, 8, pp. 188—190, September 15th, 1919.)

Grid and anode current and voltage waves at a frequency of 50, both as an amplifier and as a generator, using a standard Siemens oscillograph.

278. HARMONIC OSCILLATIONS IN DIRECTLY EXCITED ANTENNAS USED IN RADIOTELEGRAPHY. L. Lombardi. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 636—647, December, 1919.)

Deals with the author's measurements of the frequencies, decrements and relative amplitudes of the fundamental and harmonic oscillations of a directly excited artificial antenna. Marconi, brass and Boas spark gaps were used.

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279. REINFORCED HARMONICS IN HIGH-POWER ARC TRANSMITTERS. F. A. Kolster. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 648—651, December, 1919.)

A discussion of Lombardi's paper (see previous abstract). Some experiments on the directly excited antenna system of the arc station at San Francisco showed that an arc generating at 7,200 metres fundamental gave a very strong harmonic at 1,100 metres. The effect is explained in terms of reactance diagrams, and a method of eliminating the interference effects of the harmonic suggested. This consists in coupling to the antenna a closed circuit including an energy absorbing resistance, and tuned to the undesired harmonic.

280. SPARK GAPS. A. Marino. (*British Patent* 129700, November 29th, 1917. Patent accepted, July 24th, 1919.)

Various forms of multiple quenched spark gaps are described. The complete group of electrode plates is clamped together by bolts external to the electrode surfaces, and may be mounted upon a rotating shaft.

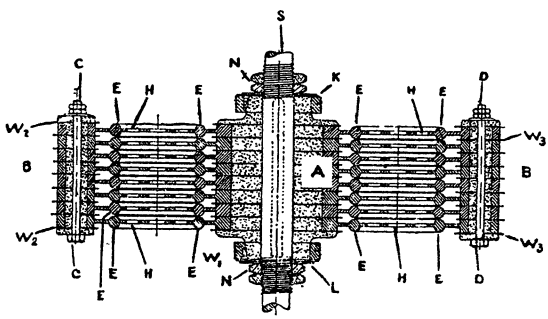

FIG. 1.

One of the forms is illustrated in Fig. 1. S is the shaft upon which the electrode plates are clamped by the nuts NN. The central portion A of the electrode plates is circular and provided with two or more extension parts BB, on which the electrode surfaces EE are formed. The separate electrode plates are kept apart by the insulating washers W_1 W_2 W_3, etc., and are also bolted together, insulated from one another, at their edges as indicated at C, D, W_2, and W_3. The spaces enclosed by the annular electrode surfaces are provided with ventilating holes HH. The electrodes are usually of silver or silvered copper, but for use on direct current the adjacent electrode surfaces may be of different shape and material. Slip rings KL are provided on the shaft and arrangements are also made for connecting the rings to any one of the plates, thus enabling the number of gaps in the circuit to be varied.

281. MODERN RADIO TRANSMITTERS OF UNDAMPED OSCILLATIONS. G. von Arco. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 558—569, November, 1919.)

A comparative discussion of the arc, the high-frequency alternator and the vacuum tube generator.

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282. SPARK GAPS. A. Marino. (*French Patent* 496118, November 23rd, 1917. Published October 28th, 1919.)

The invention relates to spark gap apparatus used in wireless telegraphy. For particulars, see the British Patent No. 129700.*

283. IMPROVEMENTS RELATING TO RADIO TELEGRAPHIC APPARATUS. M. Latour. (*British Patent* 132118, November, 1916. Patent accepted, September 11th, 1919.)

The same valve is used both for amplifying the modulation currents and also for generating the high-frequency oscillations. The microphone M, Fig. 2, is coupled through the transformer T to the grid circuit of the valve V as shown. This grid circuit also includes the coil L_1 of the reaction coupling L_1 L_2. The plate circuit of the valve includes the choking inductance L_0. The amplified modulation current produces low frequency potential variations

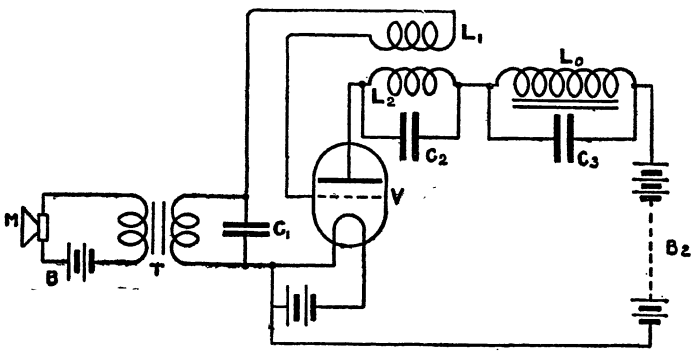

FIG. 2.

across this inductance. It therefore varies the effective plate voltage for the valve V and hence modulates the oscillations set up by reason of the reaction coupling L_1 L_2. Condensers C_2 C_3 serve to bye-pass high-frequency current across the inductances L_2 L_0. Alternatively the secondary of T and coil L_1 may be joined in parallel instead of in series and likewise L_2 and L_0 may be in parallel instead of in series if preferred.

284. IMPROVEMENTS IN POWER MODULATORS FOR RADIO TRANSMISSION. Western Electric Company, U.S.A. (*British Patent* 132058, September 19th, 1918. Patent accepted, September 11th, 1919.)

Acircuit of the high-frequency oscillation generator G (Fig. 3) is arranged to include the plate filament circuits of the valves V_1 V_2 connected in opposite directions as well as the coil L_2 for coupling to the aerial circuit A L_1 C_1 E.

* RADIO REVIEW Abstract No. 280.

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The grid circuits of these two valves are supplied with high frequency P.D's derived from the same oscillation generator G through the transformers L_3 L_4 and L_5 L_6 L_7. The intermediate circuit connecting these two transformers is tuned by the condenser C and includes the transmitting microphone M. The position of the slider on R is adjusted to bring the potentials applied to the grids of the valves into phase with the potentials in their plate circuits.

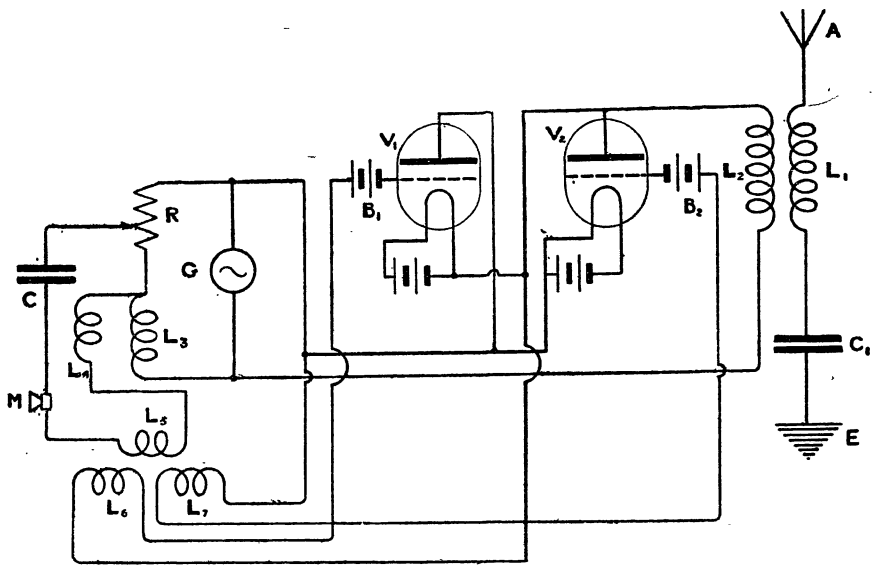

FIG. 3.

The couplings L_6 L_7 are arranged so that the microphone M produces opposite potential changes upon the grids of V_1 and V_2. Since these two valves are connected in opposite directions both half waves of the radiated energy are controlled by them. In alternative arrangements the two valves connected in opposition in this manner may be joined in shunt with the coil L_2 instead of in series with it.

285. THE "FOG-WARNING" RADIOTELEPHONE. (*Electrical Experimenter*, 7, p. 426, September, 1919.)

Describes the interior mechanism of the wireless telephone fog-warning apparatus installed at the Point Judith Light, near Narragansett Pier, R.I. (U.S.A.).

286. THE MANUFACTURE OF AMPLIFYING VACUUM TUBES. E. Rüchardt. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 619—624, November, 1919.)

An account of the technique of triode tube manufacture.

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287. TRANSMITTING AND RECEIVING APPARATUS. The Connecticut Telephone and Electric Company, Inc. (*French Patent* 496240, February 25th, 1919. Published October 30th, 1919.)

The valve described in this specification has a filament within an exhausted bulb and a grid and an anode both mounted outside the bulb. The grid and the anode may be of silver or copper deposited electrolytically.* See also British Patent No. 124721.

288. VALVE CONSTRUCTION. Osram-Robertson Lamp Works, Ltd. (*French Patent* 496479, May 3rd, 1918. Published November 7th, 1919.)

The invention relates to supporting means for the electrodes in ionic tubes, more particularly for use in wireless telegraphy. The filament is maintained in tension by a coiled spring which is attached to a pin in alignment with the filament and the axis of the spring. The pin is carried in a guide whereby thermal expansion is permitted while preventing lateral displacement. The guide may be constituted by a socket opening into an enlargement to receive the head of the pin, which enlargement is attached to the inner end of the re-entrant tube of the bulb. For further particulars, see British Patent No. 116134.

289. VALVE CONSTRUCTION. Osram-Robertson Lamp Works, Ltd. (*French Patent* 496632, May 21st, 1918. Published November 12th, 1919.)

The specification describes means for supporting the electrodes of ionic tubes, more particularly such as are employed in wireless telegraphy. The cylindrical electrode is carried by, for example, three arms on a metal clip or clips which encircle the re-entrant tubular part of the bulb. Conveniently, two clips are employed which are disposed one on each side of a protuberance on the re-entrant tubular part. The conductor is soldered to one of the clips and is also attached to a leading-in wire. The grid may consist of a wire coiled around parallel straight wires attached to the supporting arms and carried on a second re-entrant tube. For further particulars, see British Patent No. 116113.

290. VALVE CONSTRUCTION. Osram-Robertson Lamp Works, Ltd. (*French Patent* 496752, June 20th, 1918. Published November 15th, 1919.)

The invention relates to means for supporting the electrodes in ionic tubes, more particularly such as are used in wireless telegraphy. A substantially cylindrical anode is carried at each end on bars which have divergent ends and which at the said ends are attached to metal collars which fit into annular seatings, one at each end of the bulb. A convenient form of collar

* *Cf.* RADIO REVIEW Abstracts Nos. 17 and 79.

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is an elastic split ring which tends to expand to a greater diameter than the seating, and preferably, one collar is smaller than the other so as to allow it to be inserted into the tube first. For further particulars of the invention, see British Patent No. 117939.

291. AMPLIFIERS. M. Latour. (*Bulletin, Société Française des Electriciens*, 9, pp. 465—484, July, 1919. *Revue Générale de l'Électricité*, 6, pp. 709—718, November, 1919.)

After referring to the American Patents Nos. 921930 and 1041210 of 1907 of Latour and Weintraub in which the negative resistance of a mercury vapour lamp was utilised to give amplification and pointing out that such an arrangement can be adjusted to be on the point of maintaining self-sustained oscillations, the author passes on to the main subject of his paper, viz., the use of the de Forest three-electrode bulb or triode.

He refers to the types due to Lieben and Reiss, the General Electric Co., the Western Electric Co., and the so-called French type due to MM. Biguet and Peri (Brit. Pat. 126658).* He then gives the general theory of the triode amplifier, which although now published by him was incorporated in his 1916 patents. From the four resistances obtained from the plate and grid currents and potentials the amplification is calculated and the optimum value of the load or of the ratio of transformation between the plate circuit and the load. The values of the constants for the standard French valve are given. The calculation is extended to loads of different types, to amplification by retroaction, and by the use of several valves in cascade.

292. THE DESIGN OF TRIODE GENERATOR CIRCUITS. M. Vos and R. Ziegler. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 578—598, November, 1919.)

A discussion of the triode generator under the following headings: (*a*) Case of external excitation with alternator in grid circuit and anode circuit coupled to antenna; (*b*) Cases of self-excitation, phases of currents and voltages discussed; (*c*) Simple circuits; (*d*) Design of above circuits with the aim of combining uniform frequency, high efficiency and long life of triode.

293. QUANTITATIVE STUDY OF TRIODE GENERATORS WITH THE AID OF OSCILLATION CHARACTERISTICS. H. G. Möller. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 326—360. September, 1919.)

If an alternating P.D. is applied to the grid of a triode an alternating current will be produced in the anode circuit with an amplitude and phase depending on the nature of the load in the circuit. Curves having the amplitude of the anode current as ordinates and that of the grid voltage as abscissæ are called oscillation characteristics; a different curve is obtained for every value of the resistance or other load in the anode circuit. The author uses these curves to study the stability, frequency, wave form, amplitude of harmonics, etc., in a self-sustained oscillating triode.

* RADIO REVIEW Abstract No. 16.

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294. ELECTRIC CURRENT AMPLIFIERS. The Western Electric Co. (*British Patent* 130432, April, 1918. Patent accepted, August 7th, 1919.)

An amplifying system comprising two three-electrode valves, and their inter-connected circuits, is connected to two high-frequency current sources, one of which produces opposite potential variations upon the grids of the valves, while the other produces like potential variations on the grids. One of the above variable current sources is a feed-back circuit. A typical arrangement is shown in Fig. 4. The H.F. current to be amplified is applied to the

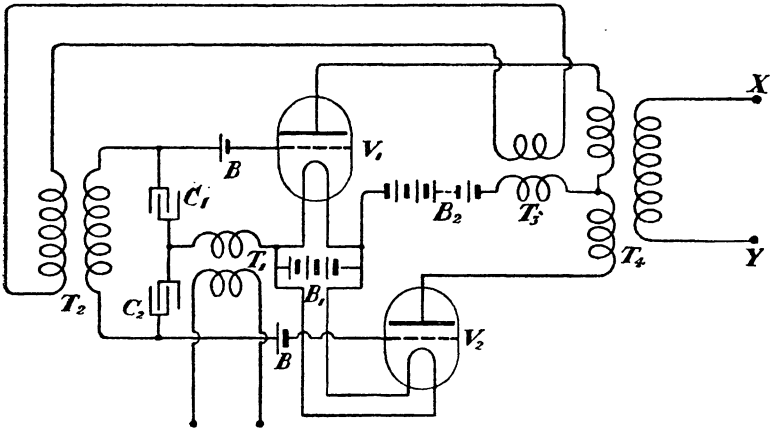

FIG. 4.

transformer T_1, and thus influences the grids of both V_1 and V_2 in parallel through the condensers C_1 C_2. The plate circuits of these valves are in parallel and supplied from the common battery B_2, through the windings of T_3 and T_4. Since equal current variations are impressed upon both windings of T_4 there is no resultant effect upon the output circuit connected to X Y, but transformer T_3 forms part of the " feed-back " circuit, and in conjunction with T_2 impresses opposite potential variations upon the grids of the two valves causing a differential action. The plate currents therefore vary in opposite phase and so produce a resultant effect on the output circuit through T_4. Various modifications are described involving the use of low-frequency fitters in the output circuits. A single valve with double grid and anode can replace the two valves in all cases.

295. TECHNICAL DEVELOPMENT OF THERMIONIC TRANSMITTERS. L. Kühn. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 395—419, September, 1919.)

A description of methods employed by the Erich Huth Co. The grid circuit is tuned to the aerial which is coupled to the anode circuit through an auto-transformer The only coupling between the grid and the anode

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circuit is that due to the valve itself. The author claims many advantages for this method of coupling. Photographs of the transmitting sets are reproduced. In the larger sizes the anode battery or dynamo is replaced by a rectifier supplied with A.C. which has been transformed up to the necessary voltage. This rectifier has a calcium oxide cathode wound with a platinum heating spiral and the two anodes are of graphite. The author discusses the reduction of the pulsations by means of choking coils and condensers. The voltage varies from 1,000 volts in the valves with 15 watts output, to 5,500 in the 2,000 watt valves. The filament is heated from the A.C. supply through a transformer and an ingenious compensating device is described whereby the heating current is kept constant in spite of the drop of voltage which occurs when the sending key is depressed.

296. ON THE DETECTING EFFICIENCY OF THE THERMIONIC DETECTOR. H. J. van der Bijl. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 603—635, December, 1919.)

Describes a modification of the " audibility method " of testing thermionic detectors for standardising purposes. The relation between the alternating grid voltage e and the alternating component of the anode current J of a triode is expressed by a convergent power series

$$J = a_1e + a_2e^2 + a_3e^3 + \ldots\ldots$$

The second term is only considered effective in detecting and the method is designed to determine the value of a_2 for any tube. Modulated radio frequency oscillations are impressed on the detector at L (Fig. 5) and the input voltages are measured by means of a Duddell thermo-galvanometer G and non-inductive resistance R. The signal produced in the telephones is matched with a known fraction of a known value of auxiliary current of the same audio frequency from the generator U. The switch S is so designed that the total resistance into which the generator works is constant for all adjustments of the shunt.

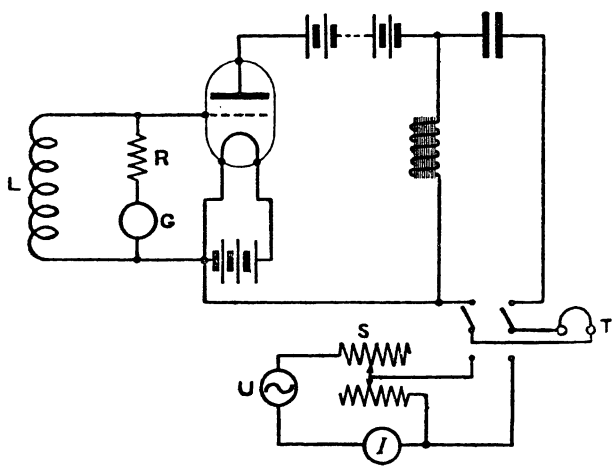

FIG. 5.

For constant input voltages the detection coefficient is a function of the " effective grid voltage " and is a maximum when the latter is equal to the

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potential drop along the filament. Methods are given for the comparison of detectors and the measurement of the amplification of triodes. In the discussion J. M. MILLER describes the method of measuring the detecting efficiency of a triode tube in use at the Bureau of Standards, Washington.

297. THE DETERMINATION OF CHARACTERISTIC CURVES OF TRIODES. R. Jaeger. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 361—385, September, 1919.)

A discussion of the connections to be employed in determining the various characteristics of a triode. A number of interesting details are discussed, such as the saturation current per watt as a function of the watts per candle, the best current for various sizes of filament. Methods are described for determining directly the slope of the ordinary characteristic curve and the voltage ratio of the triode. The following table gives the results obtained from a number of triodes of various types:

Type of Triode.	Voltage Ratio in per cent.	$\partial i_a/\partial e_g$. Amps. per Volt.
TRANSMITTING TUBES:—		
A.E.G.	5·0	18×10^{-4}
Auer-Studienges. für electrische Leuchtröhren (molybdenum wire mesh anode)	2·4	15×10^{-4}
Ditto. Type W.M. 2 (mesh anode)	1·0	$17—20 \times 10^{-4}$
C.H.F. Müller-Hamburg	2·0	18×10^{-4}
Schott u. Gen.-Jena. Type M. (copper or iron anode)	5·0	18×10^{-4}
Ditto (tantalum anode)	6·0	25×10^{-4}
Type K. (for low power)	5·0	5×10^{-4}
Siemens & Halske	5·0	18×10^{-4}
AMPLIFYING VALVES:—		
Auer-Studienges.	6·0	$1·1 \times 10^{-4}$
Deutsche Telephon-Werke (D.T.W.)	9·0	$1·8 \times 10^{-4}$
French valve	15·0	$2·5 \times 10^{-4}$
Gundelach	6·0	$1·1 \times 10^{-4}$
Dr. E. F. Huth	11·0	$2·6 \times 10^{-4}$
C.H.F. Müller-Hamburg	5·0	$3·6 \times 10^{-4}$
(R.I.W.) Seddig-Würzburg	10·0	$1·3 \times 10^{-4}$
Telefunken E.V.E. 173	10·0	$1·1 \times 10^{-4}$
Ditto. E.V.N. 171	15·0	$1·1 \times 10^{-4}$
Ditto. Type O	5·0	$1·5 \times 10^{-4}$
HETERODYNES:—		
Auer-Studienges.	5·0	$2·2 \times 10^{-4}$
French valves:—		
Model 53, 4 volts, 251	2·8	$8·0 \times 10^{-4}$
„ 53, 4 volts, 215	1·2	$8·0 \times 10^{-4}$
Telefunken, Type R.E. 16 ("U")	10·0	$3·0 \times 10^{-4}$

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The effect of small traces of gas on the characteristic curves is discussed and curves given.

298. Electrostatic Direction Finders. E. Bellini. (*Electrician*, 83, pp. 273—275, September, 1919. *L'Elettrotecnica*, 6, pp. 759—760, December, 1919, Abstract.)

The apparatus described in this article utilises electrostatic coupling between the aerials and the receiving circuits in place of the magnetic coupling customarily employed in direction finding. One of the forms

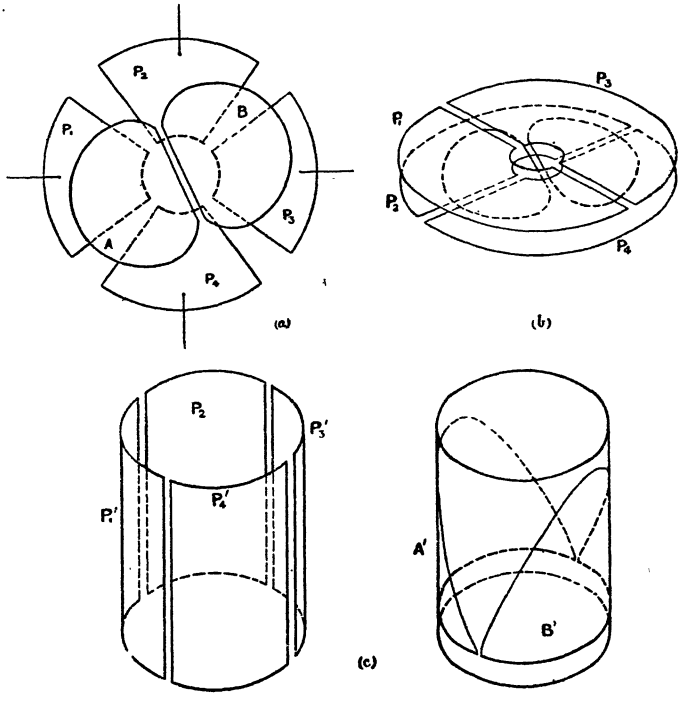

Fig. 6.

described is constituted as a special multicellular electrometer with four systems of fixed plates connected to the directive aerials, and two movable plates connected to the receiver. In Fig. 6 (*a*) and (*b*) two forms of this arrangement are indicated, $P_1P_2P_3P_4$ being the two pairs of fixed plates and A and B the movable ones. In (*b*) the two pairs of fixed plates are on separate planes and overlap.

In the second type of arrangement described in the paper, the fixed plates $P_1'P_2'P_3'P_4'$, Fig. 6 (*c*), are arranged as part of a cylinder, and two specially shaped movable plates (A'B') are arranged concentrically within them.

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299. IMPROVEMENTS RELATING TO WIRELESS DIRECTION FINDERS. R. C. Vaughan. (*British Patent* 131963, June, 1918. Patent accepted, September 11th, 1919.)

In wireless receiving apparatus the direction of incoming signals is determined by the use of a composite aerial comprising three coils A, B, B_1 (Fig. 7). The switch S is arranged to connect coil A in series with either coil B or with coil B_1. In using this arrangement the three coils are rotated together round the axis C until equality of signal strength is obtained with the switch in either position. When this is the case the plane of the aerial A indicates the direction of the incoming signals.

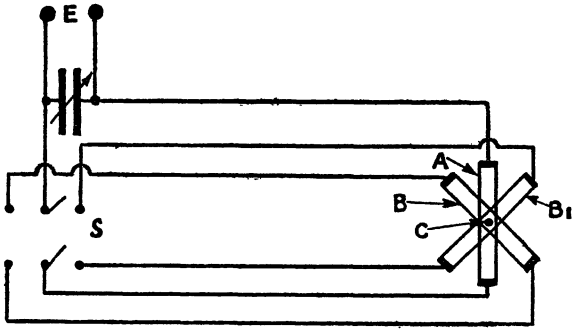

FIG. 7.

300. SHIP RADIOGONIOMETERS—FIXED OR ROTATING AERIALS? (*Le vie del Mare e dell' Aria*, 3, pp. 266—275, 1919.)

A comparison of the Bellini-Tosi and the single rotating coil systems of direction finding.

301. RECEIVING APPARATUS. A. Artom. (*French Patent* 495960, December 1st, 1917. Published October 23rd, 1919.)

The apparatus described in this specification for determining the direction of incident waves consists of two or more coils mounted to turn in a permanent magnetic field. The coils are connected to the directive receiving aerials or are traversed by currents set up by and proportional to the currents in the said receiving aerials. A pointer attached to the coils indicates on a scale the direction of the incident waves. For further particulars, see British Patent No. 124786.

302. WIRELESS TELEGRAPHY AND THE SOLAR ECLIPSE OF MAY 28TH. (*Revue Générale de l'Électricité*, 6, p. 55B, September, 1919. *Technical Review*, 5, p. 28.)

A special receiving station was erected at Meudon for reception from Ascension. This was normally only possible at night. During the eclipse, when the shadow of the moon passed between Ascension and Meudon, the signals were audible at Meudon, and as the shadow passed away the signals became weaker and disappeared completely with the end of the eclipse.

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303. On the Quantitative Determination of Electromagnetic Radiation Field Strength in Wireless Telegraphy. H. R. von Traubenberg. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 569—578, November, 1919.)

Describes a method of measuring the value of the magnetic vector *H* (using a search coil with vacuum thermo-element detector) based on Professor Braun's mathematical treatment of the subject.

304. The Wireless Station at Bandoeng (Java). (*Elektrotechnische Zeitschrift*, 40, p. 339, July, 1919.)

This station has communicated with San Francisco, 14,000 km. distant in a direction perpendicular to the antenna which is directed towards Amsterdam.

305. Improvements relating to Telephone Installations, particularly for Wireless Telegraphy. L. N. Brillouin. (*British Patents* 131054, 131055, April, 1918. Patents accepted, August 21st, 1919.)

This patent relates to special connections of multivalve "resistance-capacity" amplifiers, with the object of obtaining selective amplification for a given frequency or for a range of frequencies. The apparatus may also operate as an oscillation generator. Fig. 8 shows a system of four valves. The coupling between successive valves is provided by condensers C_2, C_3, C_4, in the well-known manner. (See also British Patent 127014.*) A special

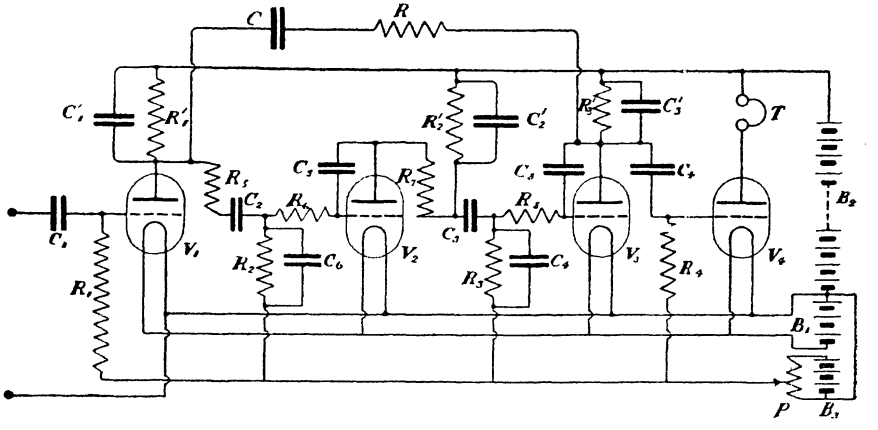

Fig. 8.

connection is made between the anodes of the first and third valves through the condenser C and resistance R. The strength of the amplified oscillations increases as the capacity of C is increased, until sustained oscillations are

* Radio Review Abstract No. 51.

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set up. The wavelength to which the apparatus resonates varies directly with

(1) the value of the resistances R_2 R_3
(2) the capacities of C_5 and C_8
(3) the capacities of C_6 and C_7 shunting R_2 and R_3;
(4) the capacities of C_1', C_2' and C_3' shunting R_1', R_2' and R_3';
(5) the value of the resistances R_5 and R_7;
(6) the value of the resistance R;
and (7) the value of the capacities C, C_2 and C_3.

When more than four valves are used the connection from C, R may be made to other valves than the third, and in that case the resonant wave length is increased by increasing the number of valves in use. The set may be arranged to amplify between certain limits of frequency—the lower limit being determined by the values of C_2 and C_3, and the upper limit by the shunt condensers C_5 and C_8.

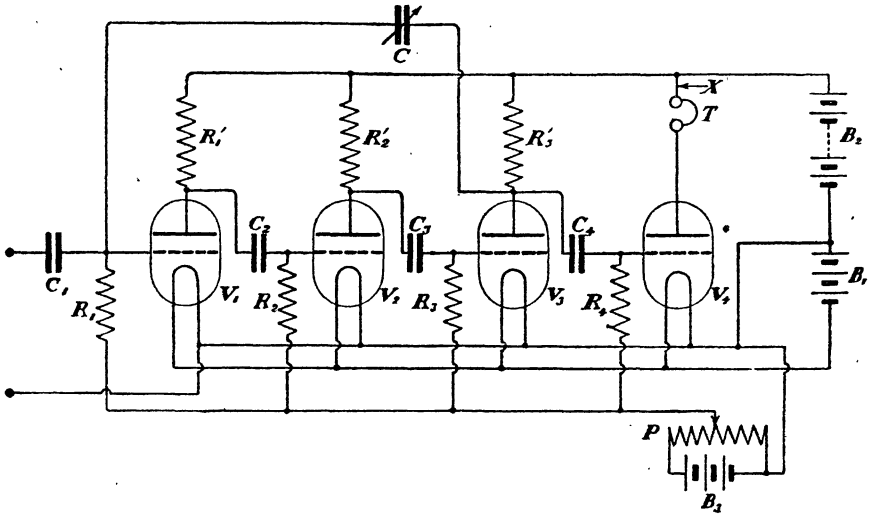

FIG. 9.

In the second of the above patents a simpler circuit is given, using a variable condenser only to couple the first valve with the plate of another one (Fig. 9). The amplification increases as the capacity of C is increased, until sustained oscillations are set up. For short waves the plate of the third valve is connected to this condenser C, but with increasing wavelengths, the connection is made to the valves in the following order: second, fifth, seventh, fourth, sixth, eighth. The resistance R_3 and condenser C_3 connected to the grid of the selected valve are increased in value until maximum amplification is obtained without "howling." In a still simpler arrangement the connection from the reaction condenser C is permanently connected to the plate of the last valve so as to reduce the necessary adjustments, and the receiving

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instrument T (or transformer supplying that instrument, when one is used) is shunted by a condenser, while a resistance and a choking inductance are placed in series with T, between it and the plate of the valve (at the point marked X in Fig. 9). To avoid stray reactive capacity, the valves are arranged in line and the resistances and capacities are grouped near the valves to reduce the length of connecting wires.

306. Improvements relating to Audion Amplifying Apparatus. M. Latour. (*British Patent* 131092, April, 1917. Patent accepted, August 21st, 1919.)

In a multivalve amplifier* the same valves are used for both high and low-frequency amplification. In Fig. 10 the high-frequency current is amplified in V_1 and V_2 (using finely laminated iron-core intervalve transformers),

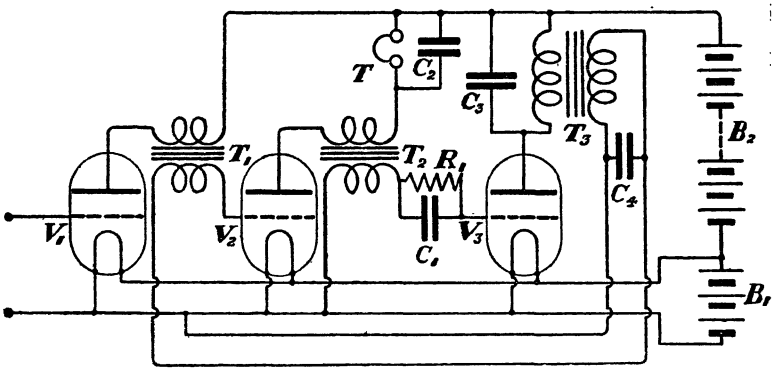

Fig. 10.

and detected in V_3. The rectified (low-frequency) current from this valve is returned through T_3 to V_2 as indicated, and the amplified L.F. current passed to the receiver T which is shunted by C_2 to prevent H.F. currents passing through it. The windings of T_3 are shunted by C_3 and C_4 for the same reason.

307. On the Use of Alternating Current for Valve Detectors. E. A. White. (*Electrical Experimenter*, 7, p. 234, July, 1919.) See also L. H. Maertens. (*Radio Nieuws*, 2, pp. 274—278, September, 1919, Abstract.)

An arrangement is described for the use of rectified A.C. for supplying the plate voltage of receiving valves, to eliminate any disturbance in the phones from the A.C. frequency. Fig. 11 is the connection scheme. An essential point is the use of the same A.C. supply for heating the valve filaments, as shown, and making the plate circuit connection to the slider of a potentiometer, P, connected across the filament of the receiving valve. By proper adjustment of this potentiometer the buzzing in the phones can be eliminated.

* See also British Patent 127318. Radio Review Abstract No. 83.

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The transformer must be very well insulated, its iron core should be earthed, and it should be kept at least 5—6 feet away from all parts of the receiving circuit proper.

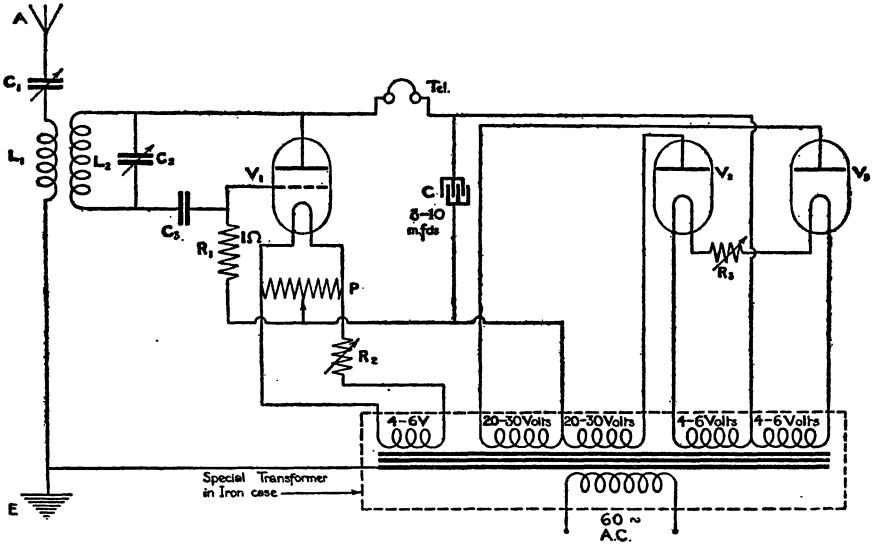

FIG. 11.

308. ON THE MEASUREMENT OF THE FREQUENCY OF ACOUSTIC AND ELECTRIC OSCILLATIONS BY A BEAT METHOD. R. Weller. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 599—608, November, 1919.)

Beats are obtained between the oscillation to be measured and the oscillation of a vacuum tube source. If an alteration dC in the capacity C of the oscillatory circuit of the tube generator produces a difference dn in the frequency as measured by the beats n, the frequency is given numerically by $2C\frac{dn}{dC}$. Many examples are given.

309. ON THE ORIGIN OF THE NOTE SPECTRUM PRODUCED BY BEAT RECEPTION. M. Wien. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 608—619, November, 1919.)

The secondary note spectrum obtained with beat reception cannot be explained as due to the harmonics of sending and receiving stations. It is due to combination tones arising from "double forcing" in a circuit not obeying Ohm's law. These combination tones have been separated from the ordinary harmonics by resonance methods both in laboratory experiments and in radio reception tests. The question of interference by harmonics and combination tones is discussed.

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310. IMPROVEMENTS IN RECEIVING CIRCUITS FOR WIRELESS TELEGRAPHY. H. J. J. M. de R. de Bellescize. (*British Patents* 132434, June, 1917; 132435, April, 1918. Patents accepted September 18th, 1919.)

Means are described for eliminating disturbing effects due to earth capacity of the valves and receiving telephones, particularly in the case of D.F. receivers. Inaccuracies in the indicated direction may arise through the receiving loop acting as an imaginary open circuit and thus setting up a second series of oscillations which are superimposed upon the main oscillations. The disturbance is removed by making the circuit as symmetrical as possible with respect to the earth. One arrangement is indicated in Fig. 12, where the capacities shown serve to render the complete arrangement more symmetrical as regards earth capacity. The condenser C_1 and auxiliary telephones T_1 balance the condenser C_3 and the main telephones T; the condenser C_2 joined to the frame of the auxiliary telephones represents the capacity of the main telephones T to the operator; the condenser C_4 and resistance R_2 represent the operator; the condenser C_5 balances the effect of the capacity between the grid and filament of the valve. The receiving arrangement may also be electrostatically screened and, if necessary, one point of the receiving loop may be connected to the screen.

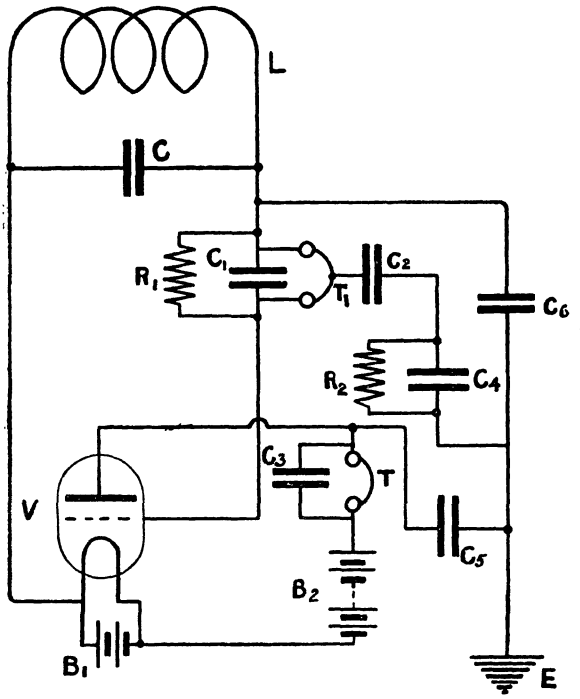

FIG. 12.

311. VALVE DETECTORS. V. J. Brochard. (*French Patent* 496562, June 20th, 1918. Published November 11th, 1919.)

The invention relates to improvements in galena wireless detectors, the improvements consisting in so constructing them that it is impossible for them to be put out of order. The construction is also such that the imme-

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diate replacement of a damaged detector is rendered possible without interfering with the remainder of the apparatus.

312. IMPROVEMENTS IN APPARATUS FOR RECEIVING RADIO SIGNALS. R. A. Weagant. (*British Patent No.* 132548, July, 1917. Patent accepted, September 25th, 1919.)

A receiving system for reducing or eliminating the effects of atmospheric and the like disturbances is described. It operates upon the principle described in the first part of RADIO REVIEW Abstract No. 18.

313. LONG WAVE RECEPTION AND THE ELIMINATION OF STRAYS ON GROUND WIRES (SUBTERRANEAN AND SUBMARINE). A. H. Taylor. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 559—583, December, 1919.)

A further account of the author's work on the properties of ground wires * with special reference to long wave reception and the elimination of strays. It is found that a best wire length is only obtained in the case of lead-covered cable lying on the face of the ground, but that this optimum length is much less sharply defined than in the previous experiment on short waves. Multiplex reception is possible as with short waves on the same ground wire so long as the local heterodyne oscillations do not interfere audibly. The ratio of signal audibility to stray audibility with ground antenna has been compared with other systems. For long waves the difference between this ratio in the case of ground antenna and rectangular aerial is not large. The best ratio of signal to stray is obtained with wires laid in salt water.

Methods of reducing the effects of strays are described, the one which

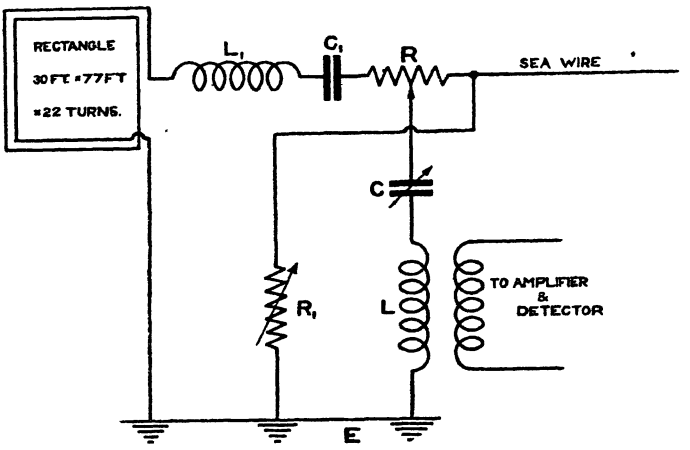

FIG. 13.

* See RADIO REVIEW Abstract No. 149.

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produced the most successful being that in which the dissimilar properties of land and sea wires were utilised. The essential part of this circuit is illustrated in Fig. 13, in which L_1 C_1 R represent an adjustable phase differential coupling.

The presence of the variable resistance R_1 seems to be necessary although its exact functioning is not understood. The ratio of improvement in readability of signals through strays with this arrangement is conservatively estimated as 8·6 to 1.

314. RECEIVING APPARATUS. Y. de Saint-Melluc. (*French Patent* 496551, May 10th, 1918. Published November 11th, 1919.)

The invention consists in means for preventing "tapping" of wireless telegraphy communications, and consists in employing two antennæ of unequal radiating power. Unequal radiation can be obtained in many ways, but particularly, the inventor proposes to do this by employing antennæ placed at different heights, or by arranging antennæ at the same height and employing different inductances connected thereto.

315. RECEIVING APPARATUS. Société Française Radio-Électrique. (*French Patent* 495915, November 3rd, 1916. Published October 22nd, 1919.)

The invention relates to wireless telegraphy and telephony receiving apparatus in which the usual antennæ are not employed. The frames employed as antennæ are formed with groups of turns which can be connected in parallel or in series with or without capacities in circuit therewith.

316. CONCENTRATED OR LOOP AERIALS. L. M. Knoll. (*Electrical Experimenter*, 7, p. 328, August, 1919.)

In this article the author appears to claim joint inventorship with T. Appleby of the use of the small loop aerial for reception, and states that Appleby discovered the directional properties of the device. Simple diagrams showing the method of connecting the loop to the detector are given.

317. TALKING THROUGH THE TREES. G. O. Squier. (*Electrical Experimenter*, 7, p. 204, July, 1919. *Electrician*, 84, pp. 111—112; 147—149, January 30th and February 6th, 1920, Abstract.)

Describes the author's researches into the use of living trees as antennæ, as carried out at the U.S. Signal Corps Laboratory near Washington.

318. WIRELESS IN CHINA. (*The Times of India—Indian Engineering Supplement*, No. 20, p. 4, September 26th, 1919.)

An illustrated article dealing with the apparatus to be used by the Chinese National Wireless Telegraph Co., and with the natural obstacles to be overcome in erecting the stations.

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319. A METHOD FOR TRANSMITTING SECRET VISUAL SIGNALS. L. R. Matout. (*British Patent* 132858, June, 1918. Patent accepted, September 23rd, 1919.)

This relates to the use of polarised light for telegraphic transmission. The light may be circularly or elliptically polarised at the transmitter and analysed at the receiver, with a view to secrecy in transmission.

320. IMPROVEMENTS RELATING TO RADIANT ENERGY SIGNALLING SYSTEMS. T. W. Case. (*British Patent* 132341, September, 1918. Patent accepted, September 10th, 1919.)

In signalling systems employing light radiation the receiving apparatus comprises a light sensitive element connected in the grid circuit of the three-electrode valve which is also arranged to generate oscillations of audible frequency. The incidence of the signalling rays on the receiver causes a variation in the frequency of the note heard in the telephone which is connected in the plate circuit of the valve. Infra-red or other invisible light rays may be used if necessary. For infra-red rays the receiver is preferably a compound of thallium and sulphur, which is particularly sensitive to these rays. For work with ultra-violet rays the receiver may be a compound of thallium and iodine. It is mentioned that the arrangement may be used for harbour defence purposes as well as for ordinary signalling.

321. TELEGRAPHY AND AVIATION. M. Delgieu. (*Annales des Postes, Télégraphes et Téléphones*, 8, pp. 382—397, September, 1919.)

Reviews the methods of radiocommunication with aircraft.

322. HIGH-FREQUENCY MULTIPLEX TELEPHONY AND TELEGRAPHY ALONG CONDUCTORS. H. Fassbender and E. Habann. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 451—478, October, 1919.)

A triode system designed before the armistice for military purposes. It can be used in conjunction with the Hughes or Siemens high-speed telegraph apparatus.

323. SOME ASPECTS OF RECENT PROGRESS IN RADIOTELEGRAPHY. G. Montefinale. (*Le vie del Mare e dell' Aria*, 3, pp. 256—265, 1919.)

A popular account of duplexing, direction finding, and high frequency amplifiers.

324. THE CONSTITUTION OF TUNGSTEN. H. Baerwald. (*Verhandlungen der Deutschen Physikalischen Gesellschaft*, 21, pp. 474—478, July, 1919.)

Deals with electronic emission from tungsten filaments.

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2. Books.

Telephony without Wires. Philip R. Coursey, B.Sc., A.M.I.E.E. (London: *The Wireless Press, Ltd.* 1919. Pp. xix. + 414. Price 15*s.* net.)

This book is a valuable addition to the literature of the subject. It contains a very complete collection of information on the various schemes, proposed and tried, relative to the electrical transmission of the sound of the voice through space without wires.

Chapter I. is introductory, and gives a classification of methods which have been used, under three heads, viz.:—(1) Conduction and Induction Methods, (2) Photophone and Thermophone Methods, and (3) Hertzian Wave Methods.

Chapters II. and III. deal with methods (1) and (2), describing Morse's and Preece's arrangements for communicating across water, the Bell photophone and the selenium cell receiver. It is interesting to note that, as the author remarks in the preface, the photophone method was resuscitated and improved for use under war conditions.

Chapter IV. describes the early attempts by Dolbear and others to transmit speech by wavelengths corresponding to voice frequencies. An immense stride was made when it was realised that, to cover any distance, Hertzian waves, modulated in amplitude by the voice, must be employed, and the first attempts, using low spark frequencies are described in this chapter. One rather wishes that the author had pointed out either in Chapter IV. (at the dividing line between the attempts to transmit at voice frequency, and those employing Hertzian frequency) or in Chapter XVI. on "modulation," that the operation of modulation is equivalent to the addition to the "carrier" wave of other waves having the same order of length, so that the energy is carried entirely by waves of Hertzian length, and not by those of the immense lengths corresponding to voice frequencies.

Chapter V. deals with the necessary conditions to be fulfilled for successful speech transmission, and the next chapter with a general consideration of "spark" generators. The different forms of "quenched" gap are then described including that due to Chaffee using copper-aluminium electrodes.

Chapter VIII. deals with the production of continuous oscillations by means of spark gaps, describing and illustrating in detail the Marconi multi-disc discharger, although the author does not state that this discharger has been successfully employed in telephony.

Chapter IX. deals with multiphase spark apparatus as used to increase the spark frequency. One would hardly think, however, that the ring phase transformer in Fig. 73 would make a very satisfactory arrangement for transforming from three phases to a larger number. It would certainly be a very poor form of transformer for ordinary power purposes, and for the purpose in question one would expect that a winding similar to that of an induction motor would give far better results.

In the next two chapters the interesting and important arc generator is dealt with, and an excellent description of the action given, both static and

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dynamic characteristics being considered. A chapter is given to a description of the various practical forms of arc oscillation generator commencing with the Poulsen arc and including the Vreeland mercury vapour oscillator. The chapter concludes with descriptions and diagrams showing various ways of coupling an arc oscillation circuit to an aerial.

Chapter XIII. deals with vacuum oscillation generators. Nearly all the matter in this chapter, however, refers to the "soft" type of tube, *i.e.*, the type in which gaseous action plays a considerable part. The "pliotron" of Langmuir is mentioned, but on the whole this chapter rather gives the impression that for generating oscillations the "soft" type is more generally used, whereas actually the tendency is all towards the "hard" or highly exhausted type. One is perhaps treading on delicate ground to suggest it, but should not the fact that an enormous stride was made by De Forest when he first added the "grid" to the simple two-electrode valve of Fleming be brought out more clearly? This addition increased the potentialities of the vacuum bulb to an unlimited extent. It turned the simple rectifier of Fleming into a repeater having enormous possibilities as to ratio of energy amplification.

It is a pity that the excellent work done by the French during the war was not available when this chapter was written, for it was the French type of valve which was used to a great extent during the war, being manufactured, with improvements, by British firms in hundreds of thousands, both for transmitting and receiving.

Chapters XIV. and XV. deal with "Alternators and Frequency Raisers," describing the Alexanderson machine (of which type one has been running for two or three years at the station at New Brunswick, on the other side of the Atlantic), the Goldschmidt machine, and the various arrangements of stationary transformers which exploit the vagaries of the magnetisation curve of iron, and turn them to useful account in frequency raising. We note that in describing the Spinelli arrangement on p. 226 the author states that one of the secondary coils is "reversed as compared with the normal 'delta' connections." If this were the case, it would result in a large E.M.F. of primary frequency. The writer has looked up the reference and finds that the connection shown is a "star" primary connection, and "delta" secondary connection, but with one corner of the delta open. This eliminates the fundamental frequency and delivers the triple frequency E.M.F. to the load. The working of this arrangement, however, was not first shown by Spinelli, but by the present writer in an article entitled "Wave Shapes in Three-phase Transformers" published in *The Electrician* on November 10th, 1905.

Chapter XVI. deals with the important subject of modulation. One is at first sight, perhaps, a little disappointed that the author does not say a little more on the general subject than is given on pp. 238 and 239. A diagram or two showing the superposition of audible upon radio frequency waves would be a considerable help to the student, as also would a brief explanation of the analysis of a modulated wave into its high frequency components. The chapter is devoted to consideration of the various ways in which a microphone may be applied to the high frequency circuit, while the next

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chapter describes the different types of microphone which have been used, including the Alexanderson magnetic amplifier.

Chapter XVIII. describes in detail several schemes of microphonic control which are particularly adaptable to certain types of oscillation generator. Chief amongst these are the schemes used to control oscillating valves. The author points out the necessity for "exhaustive quantitative testing of different microphone constructions and of different methods of control" if further real progress in microphonic control is to be made.

Chapter XIX. deals with the efficiency of transmitters, average figures being given for quenched gaps, valves, high frequency alternators, static frequency raisers, and arc generators. The concluding paragraphs describe sources of current available for radiotelephone work, both A.C. and D.C., including the combination of a transformer with rectifying valves.

A short chapter is devoted to the Braun cathode-ray tube, showing its possibilities for high frequency work, and giving curves of oscillatory currents.

Chapter XXI. is devoted to receiving apparatus. After reference to the magnetic detector, several pages are devoted to crystals, characteristic curves being given. Vacuum receivers are then discussed commencing with the Fleming valve, and passing on to the three-electrode receiver. On p. 320 an account of the action of the grid electrode is given which hardly accords with the facts, however. The author states that "a positive charge upon the grid will attract the electrons, and so prevent them from reaching the anode, if a suitable path is provided for them by which they can flow away from the grid, and if the grid has sufficient area to adequately collect them." This would mean that the grid diverts or intercepts the electron stream to the anode. Now, although it is true that at very high grid potentials the anode current may begin to fall, this effect is not used in a detecting or amplifying valve, in both of which cases the very opposite is the truth. The positive charge on the grid tends to neutralise the "space charge" and *more* electrons not less, are drawn to the plate. The deduction given in the last three lines of this page is incorrect unless it is assumed that a series condenser is placed in the grid circuit. In this latter case, owing to the curvature of the grid current characteristic, the condenser and grid are charged negatively by a train of oscillations, and the plate current falls. An application of an oscillatory potential direct to the grid, however, results in an *increase* of the average plate current if we are working at the lower bend in the plate current characteristic, and in no change of average current, if working on the straight portion. Fig. 228 illustrates the arrangement when working on the bend of the plate current curve. The addition of a few characteristic curves of valves would be a great help in this chapter. The only curve given in the book for a three-electrode valve is one on p. 184 applying to the "pliotron" or hard valve. In justice to the author, however, it must be stated that the part of the book referred to was written before the present forms of high vacuum triode were in existence, and the ideas expressed were intended to refer to the lower vacuum type in which there was a large number of positive ions present, and also a grid of larger surface area. Chapter XXI. concludes with a description of that interesting device, the thermal telephone.

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Chapter XXII. deals with receiving amplifiers, commencing with the Brown relay and passing on to the three-electrode amplifier with "cascade" combinations.

A short chapter is then given to interference prevention, and a final one on "Fields for Wireless Telephony."

There is a brief historical *résumé* of results achieved in wireless telephony since 1885, and a most excellent list of references to papers and articles. These number no less than 695, and form a most complete bibliography of the whole subject.

For any one making a special study of wireless telephony this list of references will prove an invaluable addition to the treatise.

The book is well and profusely illustrated.

R. C. CLINKER.

SELENIUM CELLS: The Construction, Care and Use of Selenium Cells with special reference to the Fritts Cell. By Thos. W. Benson. (New York: *Spon and Chamberlain*; London: *E. & F. N. Spon, Ltd.*, 1920. Pp. 63. Price 7*s*. 6*d*. net.)

It is probable—although it is not specifically so stated—that this little book is intended for the use of amateur experimenters. There are many such enthusiasts in almost every branch of science, who, while having little exact knowledge, love to dabble in what seems weird and wonderful. Much is to be found in Mr. Benson's book to tempt them to experiment with selenium and its fascinating properties. The details of manufacture and treatment, particularly of the Fritts type used by the author himself, are given with great precision. In some cases the instructions appear to be unnecessarily detailed. For example, a recipe is given for making a weight for the selenium press, while in the next sentence it is admitted that "any other weight of eight pounds can be used." The amateur reader will, no doubt, find useful the diagrams and text illustrating the electrical connections in the various experiments described.

Regarded from a purely scientific point of view the book leaves much to be desired. Dr. Fournier d'Albe's type of selenium cell is not mentioned at all, nor is his work on the "optophone," although Professor F. C. Brown's experiments in this connection find a place. It is somewhat surprising, also, to find no mention of other substances having properties similar to those of selenium. But the chief defect from the scientific aspect is loose description of experiments. As an example may be taken the statement that a Fritts cell (a type, it may be noted, in which the current flows in the same direction as the incident light) has been made whose resistance in *the light* was only $\frac{3}{10}$ per cent. of that in the dark. As no indication is given as to the intensity of the light in question, the information is worthless. Most of the well-known properties of selenium cells are mentioned with more or less detail. Two other supposed new properties are described so briefly that it is impossible to be sure what the author means. One of them, indeed, seems to be a

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palpable absurdity, viz. that the sensitivity to light of a selenium cell depends on the *kind of battery employed with it.* Thus Leclanché cells are said to be superior to bichromate cells, and Mr. Benson seems to think it possible that different cells give different *kinds* of electric current, or, as he puts it, "Is there some unrecognised force in one current that is not found in the other ?"

The style of the book is distinctly American, although simplified spelling only appears in the word "thru" and its horrible progeny "thruout." "Galvonometer" occurs frequently and invariably, and on several occasions the word "staple" is used by the author when he is apparently referring to the *stability* of selenium cells. The grammar, also, is sometimes shaky, as the following sentence shows: "The supplies required are chemically pure selenium, specify electrolytic selenium for electrical purposes when ordering and the proper material will be supplied." One cannot help feeling that, had Mr. Benson's book been prepared with more care both in its scientific and literary features, its value would have been much enhanced.

A. O. RANKINE.

Books Received.

SELECTED STUDIES IN ELEMENTARY PHYSICS: a Handbook for the Wireless Student and Amateur. By E. Blake, A.M.I.E.E. (London: *The Wireless Press, Ltd.* 1920. Pp. viii. + 176. Price 5s. net.)

TREATMENT OF HARMONICS IN ALTERNATING CURRENT THEORY BY MEANS OF A HARMONIC ALGEBRA. By A. Press. (Berkeley, U.S.A.: *The University of California Press.* 1919. Pp. 66. Price $1.00.)

COURS ELÉMENTAIRE DE TÉLÉGRAPHIE SANS FIL. By G. Viard. (Paris: *Librairie de l'Enseignement Technique.* 1919. Pp. 303. Price 12 fr.)

MESURES PRATIQUES EN RADIOACTIVITÉ. By W. Makower and H. Geiger. (Paris: *Gauthier Villars et Cie.* 1919. Pp. viii. + 182. Price 12 fr.)

WIRELESS TELEGRAPHY. By W. H. Marchant. (London: *Sir Isaac Pitman and Sons, Ltd.* 1920. Pp. ix. + 305. Price 7s. 6d. net.)

LA THÉORIE ET LA PRATIQUE DES RADIOCOMMUNICATIONS. Vol. I., INTRODUCTION. By L. Bouthillon. (Paris: *Librairie Delagrave.* 1919. Pp. xiv. + 193. Price 20 fr.)

RADIO EQUIPMENT. By Wireless Speciality Apparatus Co. (Boston, Mass., U.S.A.: *Published by the Company.* 1919. Pp. 83.)

Contains excellently illustrated descriptions of the Company's products together with a collection of useful formulæ and curves relative to radio measurements.

Correspondence.

"THE THERMIONIC VALVE AND ITS DEVELOPMENT IN RADIOTELEGRAPHY AND RADIOTELEPHONY."

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—Referring to the reply of Professor Fleming on the above subject, I beg to thank Professor Fleming for his willingness to refer to my paper of 1916 on the three-electrode valve in the next edition of his book.

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The theory of the three-electrode valve expounded in my paper has already been referred to by different authors in the following manner :—

Professor Hazeltine writes in the *Proceedings of the Institute of Radio Engineers* for April, 1919, page 167: "Equations of this form ($i_p = e_p g_p + e_g g_m + c$) seem to have been first employed by Latour in the *Electrician*, December 1st, 1916, in discussing amplification."

Mr. John Miller of the Bureau of Standards, Washington, in his last paper on "Dependence of the Input Impedance of a Three-electrode Vacuum Tube upon the Load in the Plate Circuit," discussing the case when there is a measurable grid current, says: "All these facts are implicitly contained in the equations (5) derived by M. Latour in his paper on the "Theoretical Discussion of the Audion,' *Electrician*, 78, p. 280, 1916."

The correctness of these equations (5) of mine is shown again by the last paper of Professor Press which appeared in the issue of the *Electrician* of January 9th, 1920 (see page 35). In this paper Professor Press, discussing the work of Captain L. B. Turner, derives for *potential magnification* and *current amplification* equations corresponding to equations (5) of my paper of 1916.

MARIUS LATOUR.

Paris,
February 10th, 1920.

TRIODE NOMENCLATURE AND SYMBOLS.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—I am afraid Mr. Turner's memory has played him false. In a conversation with him in December, 1918, I suggested terms for each of the *four* conductances of a triode clearly distinguishing between $\partial i_a/\partial v_g$ and $\partial i_g/\partial v_a$. Hazeltine in his paper on "Oscillating Audion Circuits" * used the term "mutual conductance" (a term obviously ambiguous) and feeling the need of names for all four conductances I suggested to Mr. Turner and to many other workers on triodes, the following terms :—

$\partial i_a/\partial v_g$ Mutual anode-grid conductance.
$\partial i_a/\partial v_a$ Anode conductance.
$\partial i_g/\partial v_g$ Grid conductance.
$\partial i_g/\partial v_a$ Mutual grid-anode conductance.

If we omit the word "mutual" (as one possibly would do in conversation) in the first and last cases, it will be seen that these terms are identical with those of Mr. Turner's "Colloquial Abbreviation" column. With the symbols suggested for these terms I find myself in complete agreement. In a full scheme of nomenclature and symbols it might however be useful to indicate the two methods of deriving the voltage amplification factor ν, *i.e.* a_g/a_a and $-\partial v_a/\partial v_g$.

E. V. APPLETON.

Cambridge,
March 6th, 1920.

* *Proceedings of the Institute of Radio Engineers*, April, 1918.

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THE RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. 1 MAY, 1920 NO. 8

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THE
RADIO REVIEW

VOL. I MAY, 1920 NO. 8

Oscillations obtained by Coupling a Secondary Circuit with a Continuous Wave Valve Oscillator.*

By Prof. J. S. TOWNSEND, M.A., F.R.S.

(1) When two oscillatory circuits of small resistance are coupled by mutual induction between the coils the frequencies of the free oscillations are given by the equation

$$(L_1C_1p^2 - 1)(L_2C_2p^2 - 1) = M^2C_1C_2p^4 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

L_1 and L_2 being the self-inductions of the two circuits, C_1 and C_2 the capacities, M the mutual induction between the two coils and $p/2\pi$ the frequency.

If y be substituted for $1/p^2$ the quadratic equation (2) is obtained

$$(L_1C_1 - y)(L_2C_2 - y) = M^2C_1C_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

the two roots being proportional to the squares of the wavelengths of the two free oscillations.

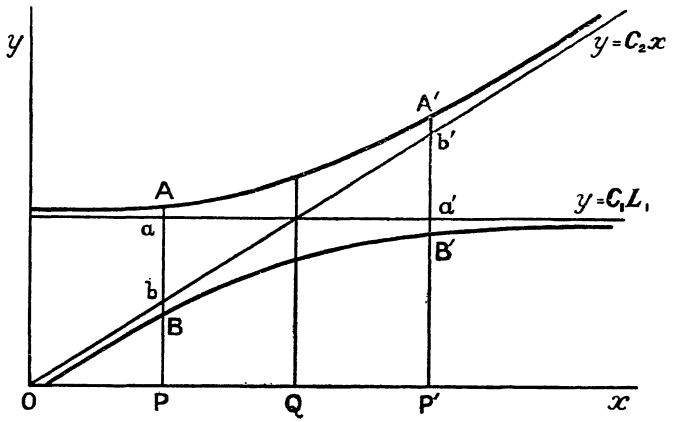

FIG. 1.

The effect of changing the oscillation constant L_2C_2 of one of the circuits

* Paper received November 15th, 1919.

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by means of an adjustable inductance $L_2 = x$ may be seen by constructing the hyperbola (Fig. 1) represented by the equation

$$(L_1C_1 - y)(C_2x - y) = M^2C_1C_2 \quad \ldots\ldots\ldots \quad (3)$$

The two lines $L_1C_1 = y$ and $C_2x = y$ are the asymptotes, and the two branches of the curve correspond to the oscillations of long and short wavelength.

Thus for any value OP of the inductance L_2, the ordinates PA and PB are proportional to the squares of the wavelengths of the two free oscillations when the circuits are coupled, and Pa and Pb are proportional to the squares of the wavelengths of the two independent circuits ($M = 0$).

(2) Let oscillations of constant amplitude be maintained in the first circuit by connecting it to a three-electrode valve, and let the current in the second circuit be maintained by the induction between the two coils, as in a transformer (see Fig. 2). For any given value x of the self-induction L_2 of the secondary circuit, there are two possible modes of oscillation and the squares of the corresponding wavelengths are given by the points A and B on the branches of the hyperbola.

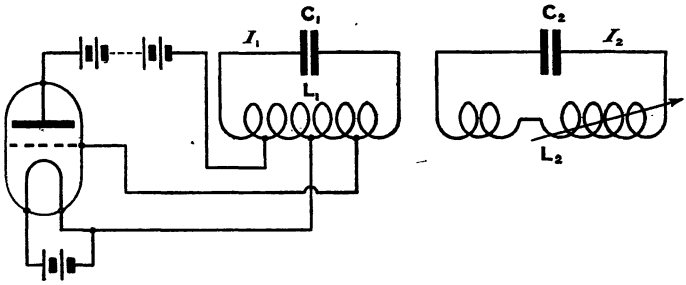

FIG. 2.

In practice two oscillations of different wavelengths very seldom occur simultaneously and the mode in which the system tends to oscillate is the one in which the wavelength is nearest to that of the primary circuit L_1C_1.

The ratio of the amplitudes of the currents in the two circuits, for each mode of oscillation, may be found geometrically as follows:

Let R_1 and R_2 be the resistances of the two circuits, i_1 and i_2 the oscillatory currents in the coils.

The equation for the current i_2 is

$$L_2\frac{di_2}{dt} + R_2i_2 = -M\frac{di_1}{dt} - v_2 \quad \ldots\ldots\ldots \quad (4)$$

where v_2 is the potential difference between the terminals of the condenser C_2.

The current i_2 and the potential v_2 are connected by the relations

$$i_2 = C_2\frac{dv_2}{dt},$$

and

$$\frac{di_2}{dt} = C_2\frac{d^2v_2}{dt^2} = -p^2C_2v_2,$$

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so that v_2 may be eliminated from equation (4) and the relation between the currents becomes

$$\left(L_2 - \frac{1}{C_2 p^2}\right)\frac{di_2}{dt} + R_2 i_2 = -M\frac{di_1}{dt} \quad \ldots\ldots\ldots \quad (5)$$

In the cases to be considered, M is supposed to be constant and comparatively large so that $\left(L_2 p - \frac{1}{C_2 p}\right)$ is large compared with R_2, and the relation between the amplitudes I_1 and I_2 of the two currents is found, approximately, by omitting the term $R_2 i_2$ in equation (5).

Thus
$$I_2 = \frac{MC_2 I_1}{L_2 C_2 - y}$$

When the system is oscillating with the longer wavelength and $L_2 = \mathrm{OP}$ (Fig. 1),

$$L_2 C_2 = \mathrm{Pb},$$

and
$$y = \mathrm{PA}.$$

In this case
$$I_2 = \frac{MC_2 I_1}{\mathrm{Ab}}, \quad \ldots\ldots\ldots \quad (6)$$

and if L_2 be increased the length Ab diminishes continuously as L_2 passes through the value OQ corresponding to resonance. Thus if I_1 were to remain constant I_2 would not reach a maximum at the point of resonance but would increase with L_2 as long as the system continued to oscillate with the longer wavelength.

When the oscillations are of the shorter wavelength

$$I_2 = \frac{MC_2 I_1}{\mathrm{Bb}} \quad \ldots\ldots\ldots \quad (7)$$

The length Bb increases as L_2 is increased, and in this case I_2 diminishes and becomes very small when L_2 is greater than OQ.

The maxima values of I_2 which are obtained near the point of resonance, are due to the fact that the wavelength changes abruptly from the long wavelength represented by the upper branch of the hyperbola to the short wavelength represented by the lower branch as L_2 is increased from OP to OP′.

(3) In order to explain the change of wavelength it is necessary to consider the effective resistance of the oscillating system. The secondary circuit adds to the resistance, and its effect is the same as if a resistance r_1 were introduced in series with the inductance and condenser of the primary circuit which would bring the resistance of the valve circuit to the value $(R_1 + r_1)$.

It is seen from equation (5) that the effect of the condenser in the secondary circuit is the same as if the secondary were a continuous circuit of resistance R_2 and the self-induction reduced to $l_2 = L_2 - \frac{1}{C_2 p^2}$. Hence as in an

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ordinary transformer the reaction of the secondary has the effect of increasing the resistance of the primary by the amount

$$r_1 = \frac{M^2p^2R_2}{l_2^2p^2 + R_2^2}.$$

As R_2^2 is small compared with $l_2^2p^2$ the value of r_1 becomes approximately

$$\begin{aligned} r_1 &= \frac{M^2p^2R_2}{\left(L_2p - \frac{1}{C_2p}\right)^2} \\ &= \frac{M^2p^4C_2^2R_2}{(L_2C_2p^2 - 1)^2} \\ &= \frac{C_2}{C_1} \cdot \frac{L_1C_1p^2 - 1}{L_2C_2p^2 - 1} \cdot R_2 \\ &= \frac{C_2}{C_1} \cdot \frac{L_1C_1 - y}{C_2x - y} \cdot R_2 \quad \ldots\ldots\ldots \quad (8) \end{aligned}$$

where y is one of the ordinates PA or PB of the hyperbola corresponding to the inductance $L_2 = OP$.

When the system oscillates with the longer wavelength the resistance r_1 is

$$r_1 = \frac{C_2}{C_1} \cdot \frac{Aa}{Ab} \cdot R_2 \quad \ldots\ldots\ldots \quad (9)$$

which is comparatively small when L_2 is less than OQ since Aa is then less than Ab. But when L_2 is increased above the value OQ the ratio Aa/Ab becomes very large and the oscillation of the longer wavelength would not be maintained by the valve as the effective resistance of the valve circuit becomes so large.

When the system oscillates with the shorter wavelength r_1 is

$$r_1 = \frac{C_2}{C_1} \cdot \frac{Ba}{Bb} \cdot R_2 \quad \ldots\ldots\ldots \quad (10)$$

which is comparatively small when L_2 is large. But when L_2 is reduced below the value OQ, the value of r_1 (equation (10)) becomes very large and the oscillations of short wavelength are not maintained.

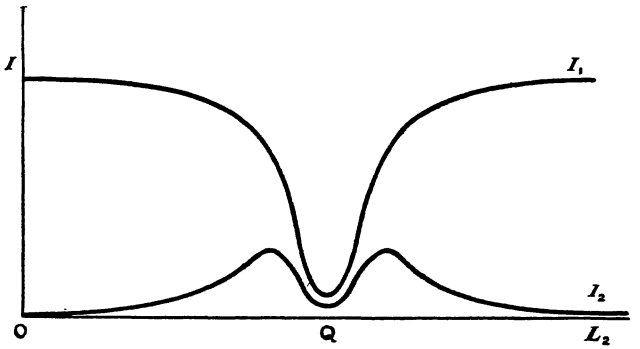

FIG. 3.

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(4) The effects observed by making continuous changes in the inductance L_2 of a circuit closely coupled with a valve oscillator are easily explained by means of the hyperbola.

There are two cases which may be considered, depending on the arrangement of the valve circuit.

When the circuit L_1C_1 is connected as in Fig. 2 so that valve reaction slightly exceeds the value required to start oscillations, a large oscillating current I_1 is obtained with the circuit L_2C_2 uncoupled, but a small increase in the resistance R_1 makes a large decrease in I_1. When the second circuit is coupled with the valve circuit and the inductance L_2 is increased from a small value to the point corresponding to resonance the ratio Aa/Ab (Fig. 1) increases and the additional resistance r_1 (equation (9)) reduces the oscillating current I_1. This current may become zero before the inductance reaches the point of resonance. After passing the resonance point the oscillations start again but the wavelength is now represented by the lower branch of the hyperbola corresponding to the smaller resistance r_1 (equation (10)) which decreases continuously as L_2 increases.

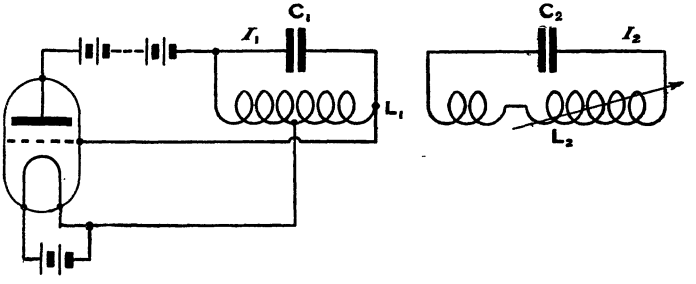

FIG. 4.

The variations in the currents thus obtained are represented in Fig. 3.

The current I_1 has a minimum value and may become zero near the point of resonance $L_2 = OQ$.

With the smaller inductances L_2 the ratio of the currents I_2/I_1 is given by equation (6) which shows that I_2 is very small when L_2 is small. As L_2 increases I_2 increases and attains a maximum value below the point of resonance.

After passing through a minimum value with I_1 and an abrupt change of wavelength I_2 attains another maximum and as shown by equation (7) becomes very small with large values of L_2.

(5) When the valve reactance is increased as in Fig. 4, the current I_1 with the circuit L_2C_2 uncoupled is reduced but it is not so much affected by variations in the resistance R_1, and the oscillations will be maintained when the effective resistance of the circuit is considerably increased.

When the second circuit is coupled to the valve circuit and the inductance L_2 increased from a small value, the oscillations which begin on the longer wavelength persist but the amplitude I_1 diminishes as L_2 passes

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through the point of resonance. At a point A_1 (Fig. 5) the additional resistance r_1 due to the secondary circuit becomes so large that these oscillations cease and the oscillations of shorter wavelength B_1 for which r_1 is comparatively small take place instead. At the same time an abrupt increase takes place in the current I_1 and a corresponding reduction in the current I_2.

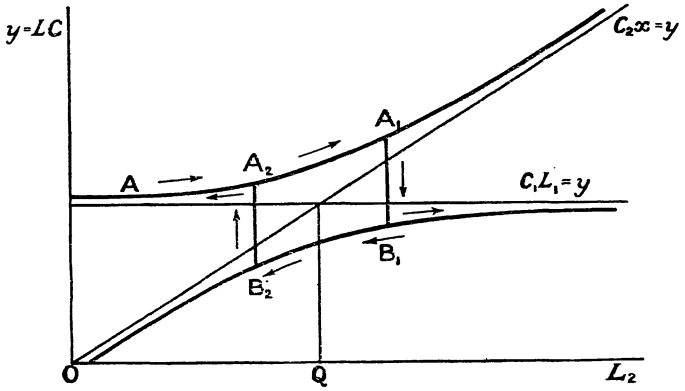

FIG. 5.

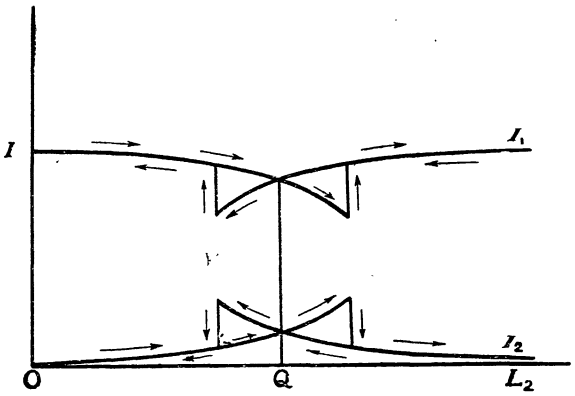

FIG. 6.

These changes in I_1 and I_2 are represented by the curves (Fig. 6), the arrows indicating the direction in which L_2 is changed. When L_2 is reduced from a large to a small value the oscillations of the shorter wavelength persist until a point B_2 (Fig. 5) below the point of resonance is obtained, the wavelength then changing from B_2 to A_2. A corresponding abrupt increase in I_1 and reduction in I_2 is obtained at the same time as shown by the curves (Fig. 6) with the arrows pointing to the left.

When the coupling is reduced a single maximum value of I_2 is obtained and the change of wavelength in passing through the point of resonance is not noticeable.

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Damped Oscillations in Coupled Circuits.

By G. BRAMWELL EHRENBORG.

(*Continued from page* 336.)

Before going any further with the integration of equations (9) it is desirable to consider another matter closely related to what has been said about Δa, Δp, etc. If we compare equations (9) with equations (1), from which they are derived, we see that they have certain features in common. In each equation there are three terms involving only one of the dependent variables and a fourth term involving only the other. That being so, there is no apparent reason why we should not be able to integrate equations (1) as they stand, if only k is small enough, instead of going to the trouble of transforming to x and y, for when k is small the correspondence between the two sets of equations seems to be very close. The difficulties appear when we proceed to the second approximation.

Consider the case where $u_1 = u_2$ and $R_1C_1 = R_2C_2$. If we put $\frac{R_1C_1}{u_1} = 2\eta$ and $\frac{1}{u_1} = s^2$, equations (1) then become

$$(D^2 + 2\eta D + s^2)\, v_1' + k\frac{u_2}{u_1} D^2 v_2' = 0$$

$$k\frac{u_1}{u_2} D^2 v_1' + (D^2 + 2\eta D + s^2)\, v_2' = 0, \text{ and consequently}$$

$$\{(D^2 + 2\eta D + s^2)^2 - k^2 D^4\}\, v_1' = 0$$

When k is small, the first approximation to one of the particular solutions of this equation is $v_1' = \epsilon^{-\eta t + it\sqrt{s^2 - \eta^2}} = \epsilon^{\sigma t}$, say. When we proceed to the second approximation and no longer neglect k^2 the solution in question becomes $\epsilon^{(\sigma + \Delta\sigma)t}$; we calculate the value of $\Delta\sigma$ on the assumption that its square may be neglected. We obtain

$$\{\sigma^2 + 2\eta\sigma + s^2 + 2(\sigma + \eta)\Delta\sigma\}^2 - k^2(\sigma^4 + 4\sigma^3\Delta\sigma) = 0,$$

and since $\sigma^2 + 2\eta\sigma + s^2 = 0$, this reduces to

$$\frac{\Delta\sigma}{\sigma} = -\frac{1}{4}.$$

Hence the second approximation differs from the first by 25 per cent., so that if we wish to obtain any results worth having by this method, we must work out the third approximation at the very least, and probably several more. When $u_1 \neq u_2$ and $R_1C_1 \neq R_2C_2$ the algebra becomes very involved, so we infer that equations (1) as they stand are quite unsuitable for integration.

To return to equations (9); writing $\sqrt{p^2 - \alpha^2} = p'$ and $\sqrt{q^2 - \beta^2} = q'$ for brevity, we have seen that when k is not too small, particular solutions are obtained by equating x to one or other of the quantities $\epsilon^{-\alpha t \pm ip't}$,

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$\epsilon^{-\beta t \pm iq't}$. If we had eliminated x instead of y from (9), equation (13) would have been reproduced though of course y would have appeared as the dependent variable instead of x; consequently equations (9) are satisfied if we equate y to any of the above four exponentials. If the ratio of the constants A and C is properly chosen, the following pair of values will satisfy the equations:

$$x = A\epsilon^{-\alpha t + ip't}, \quad y = C\epsilon^{-\alpha t + ip't}.$$

What that ratio must be we can determine by substituting these values in the second of equations (9).

We find $$C = \frac{g(\alpha - ip')}{(\alpha - ip')^2 - 2\beta(\alpha - ip') + q^2} A$$

or, $$\frac{C}{A} = g\frac{2(\alpha q^2 - \beta p^2) + \alpha(p^2 - q^2) + ip'(p^2 - q^2)}{(p^2 - q^2)^2 + 4(\alpha q^2 - \beta p^2)(\alpha - \beta)}.$$

In order to simplify the determination of the integration constants as much as possible we will neglect all quantities which contain $R_1C_1 - R_2C_2$ as a factor (such as f, g, $\alpha q^2 - \beta p^2$) if they contain another resistance as a further factor, or in other words, we will neglect all quantities which contain the factor $\left(\frac{R_1C_1}{R_2C_2} - 1\right)a^2$, where a has the same meaning as on Figs. 1—6. This entails little more labour than if we were to neglect all quantities without distinction which contain a^2 and gives us the advantage of getting a solution which is exact when $R_1C_1 = R_2C_2$, and not a mere approximation.

That being the case, we see that

$$\frac{C}{A} = g\frac{ip'}{p^2 - q^2}.$$

Proceeding in a similar manner, we find three other pairs of values which satisfy equations (9), namely

$$x = B\epsilon^{-\alpha t - ip't} \qquad y = -g\frac{ip'}{p^2 - q^2} B\epsilon^{-\alpha t - ip't}$$

$$x = -f\frac{iq'}{p^2 - q^2} H\epsilon^{-\beta t + iq't} \qquad y = H\epsilon^{-\beta t + iq't}$$

$$x = f\frac{iq'}{p^2 - q^2} K\epsilon^{-\beta t - iq't} \qquad y = K\epsilon^{-\beta t - iq't}$$

Equations (9) are therefore also satisfied by

$$x = A\epsilon^{-\alpha t + ip't} + B\epsilon^{-\alpha t - ip't} - \frac{ifq'}{p^2 - q^2} H\epsilon^{-\beta t + iq't} + \frac{ifq'}{p^2 - q^2} K\epsilon^{-\beta t - iq't}$$

$$y = \frac{igp'}{p^2 - q^2} A\epsilon^{-\alpha t + ip't} - \frac{igp'}{p^2 - q^2} B\epsilon^{-\alpha t - ip't} + H\epsilon^{-\beta t + iq't} + K\epsilon^{-\beta t - iq't}$$

As this solution contains four arbitrary constants, it is evidently the complete integral.

Transforming imaginary exponentials to sines and cosines,

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$$\left.\begin{aligned} x &= \epsilon^{-\alpha t}\{C\cos p't + D\sin p't\} - \\ &\qquad \frac{f\epsilon^{-\beta t}}{p^2-q^2}\left\{(\beta F + q'G)\cos q't - (q'F - \beta G)\sin q't\right\} \\ y &= \frac{g\epsilon^{-\alpha t}}{p^2-q^2}\left\{(\alpha C + p'D)\cos p't - (p'C - \alpha D)\sin p't\right\} + \\ &\qquad \epsilon^{-\beta t}\{F\cos q't + G\sin q't\} \end{aligned}\right\} \quad (17)$$

To determine the integration constants we shall assume that when $t = 0$, $v_1 = V_1$, $v_2 = i_1 = i_2 = 0$. Since $i_1 = -C_1\dot{v}_1$ and $i_2 = -C_2\dot{v}_2$, we find by (7) that this is equivalent to $x = \frac{ku_1V_1}{p^2\sqrt{L_1}}$, $y = \frac{ku_1V_1}{q^2\sqrt{L_1}}$, $\dot{x} = \dot{y} = 0$.

By differentiating (17),

$$\dot{x} = -\epsilon^{-\alpha t}\{(\alpha C - p'D)\cos p't + (p'C + \alpha D)\sin p't\} + \frac{fq^2}{p^2-q^2}\left\{F\cos q't + G\sin q't\right\}\epsilon^{-\beta t}$$

$$\dot{y} = -\frac{gp^2\epsilon^{-\alpha t}}{p^2-q^2}\left\{C\cos p't + D\sin p't\right\} - \epsilon^{-\beta t}\{(\beta F - q'G)\cos q't + (q'F + \beta G)\sin q't\}$$

Hence, when $t=0$,

$$\begin{aligned} C - \frac{fq'}{p^2-q^2}G &= \frac{ku_1V_1}{p^2\sqrt{L_1}} \\ \frac{gp'}{p^2-q^2}D + F &= \frac{ku_1V_1}{q^2\sqrt{L_1}} \\ -\alpha C + p'D + \frac{fq^2}{p^2-q^2}F &= 0 \\ -\frac{gp^2}{p^2-q^2}C - \beta F + q'G &= 0 \end{aligned}$$

These equations are easily solved to the degree of accuracy required, and the solutions are

$$C = \frac{ku_1V_1}{p^2\sqrt{L_1}} \qquad D = \frac{ku_1V_1}{p^2\sqrt{L_1}}\left(\frac{\alpha}{p'} - \frac{fp}{(p^2-q^2)}\right)$$

$$F = \frac{ku_1V_1}{q^2\sqrt{L_1}} \qquad G = \frac{ku_1V_1}{q^2\sqrt{L_1}}\left(\frac{\beta}{q'} + \frac{gq}{(p^2-q^2)}\right)$$

Having determined the values of the integration constants, we now substitute x and y in equations (8) and find after some easy algebra,

$$v_1 = \frac{V_1\left(\frac{1}{q^2} - u_1\right)}{\frac{1}{q^2} - \frac{1}{p^2}}\epsilon^{-\alpha t}\left[\cos p't + \left\{\frac{\alpha}{p'} - 2\left(u_1 - \frac{1}{p^2}\right)\frac{R_1C_1 - R_2C_2}{p\left(\frac{1}{q^2} - \frac{1}{p^2}\right)^2}\right\}\sin p't\right] +$$

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$$+\frac{V_1\left(u_1-\frac{1}{p^2}\right)}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\beta t}\left[\cos q't+\left\{\frac{\beta}{q'}+2\left(\frac{1}{q^2}-u_1\right)\frac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\right\}\sin q't\right];$$

$$v_2=-\sqrt{\frac{L_2}{L_1}}\cdot\frac{V_1ku_1}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\alpha t}\left[\cos p't+\left\{\frac{\alpha}{p'}-(u_1-u_2)\frac{R_1C_1-R_2C_2}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\right\}\sin p't\right]+$$

$$+\sqrt{\frac{L_2}{L_1}}\cdot\frac{V_1ku_1}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\beta t}\left[\cos q't+\left\{\frac{\beta}{q'}-(u_1-u_2)\frac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\right\}\sin q't\right];$$

and by differentiating,

$$i_1=\frac{C_1V_1\left(\frac{1}{q^2}-u_1\right)p}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\alpha t}\left[\frac{p}{p'}\sin p't+2\left(u_1-\frac{1}{p^2}\right)\frac{R_1C_1-R_2C_2}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\cos p't\right]+$$

$$+\frac{C_1V_1\left(u_1-\frac{1}{p^2}\right)q}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\beta t}\left[\frac{q}{q'}\sin q't-2\left(\frac{1}{q^2}-u_1\right)\frac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\cos q't\right];$$

$$i_2=-\sqrt{\frac{L_2}{L_1}}\cdot\frac{C_2V_1ku_1p}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\alpha t}\left[\frac{p}{p'}\sin p't+(u_1-u_2)\frac{R_1C_1-R_2C_2}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\cos p't\right]+$$

$$+\sqrt{\frac{L_2}{L_1}}\cdot\frac{C_2V_1ku_1q}{\frac{1}{q^2}-\frac{1}{p^2}}\epsilon^{-\beta t}\left[\frac{q}{q'}\sin q't+(u_1-u_2)\frac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}\cos q't\right]$$

It is at once evident that when $t=0$ we have $v_1=V_1$ and $v_2=i_1=i_2=0$. To check the accuracy of our work we may substitute the above values in the equations from which we started. It is easy to verify that they are satisfied to the required degree of accuracy if we make use of equations (4) and (5). The work is particularly simple if $R_1C_1=R_2C_2$, when it is found that the solution is exact.

As a rule it is more important to know what is happening in the secondary circuit than in the primary, so we will give some further attention to v_2 and i_2. If we put $(u_1-u_2)\frac{R_1C_1-R_2C_2}{p\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}=\tan\theta$ and $(u_1-u_2)\frac{R_1C_1-R_2C_2}{q\left(\frac{1}{q^2}-\frac{1}{p^2}\right)^2}=\tan\phi$, we find, always remembering the degree of accuracy at which we are aiming,

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$$v_2 = \sqrt{\frac{L_2}{L_1}} \cdot \frac{V_1 k u_1}{\frac{1}{q^2} - \frac{1}{p^2}} \left[-\frac{p}{p'} \epsilon^{-\alpha t} \cos\left(p't + \theta - \tan^{-1}\frac{\alpha}{p'}\right) + \right.$$

$$\left. + \frac{q}{q'} \epsilon^{-\beta t} \cos\left(q't + \phi - \tan^{-1}\frac{\beta}{q'}\right) \right]$$

$$i_2 = \sqrt{\frac{L_2}{L_1}} \cdot \frac{C_2 V_1 k u_1}{\frac{1}{q^2} - \frac{1}{p^2}} \left[-\frac{p^2}{p'} \epsilon^{-\alpha t} \sin(p't + \theta) + \frac{q^2}{q'} \epsilon^{-\beta t} \sin(q't + \phi) \right]$$

Each of v_2 and i_2 are seen to consist of two terms, one with the frequency $\frac{p'}{2\pi}$ and the other with $\frac{q'}{2\pi}$. These two terms are often referred to as the principal or normal modes of oscillation of v_2 (or i_2, as the case may be) and the change of variables from v_1 and v_2 to x and y is called in dynamics "reduction to normal co-ordinates."

In most practical applications we may of course neglect $\frac{\alpha^2}{p^2}$ and $\frac{\beta^2}{q^2}$ in comparison with unity, so that we may put $\frac{p}{p'} = \frac{q}{q'} = 1$, $\frac{\alpha}{p'} = \frac{\alpha}{p}$ and $\frac{\beta}{q'} = \frac{\beta}{q}$. The angles $\tan^{-1}\frac{\alpha}{p}$ and $\tan^{-1}\frac{\beta}{q}$ may be readily found from Figs. 1—4, and θ and ϕ from Fig. 6.

It is of interest to know how the constant factors in the expression for i_2 vary as the ratio $\frac{u_1}{u_2}$ alters. To express them as functions of this ratio we must make some assumption as to how the inductances and capacities involved in u_1 and u_2 vary; it will be assumed here that L_1 L_2 and C_2 remain constant and that C_1 alone varies. Then we may write i_2 in the form

$$i_2 = -\sqrt{\frac{C_2}{L_1}} V_1 \left(\frac{k u_1 p \sqrt{u_2}}{\frac{1}{q^2} - \frac{1}{p^2}} \right) \epsilon^{-\alpha t} \sin(p't + \theta) +$$

$$+ \sqrt{\frac{C_2}{L_1}} V_1 \left(\frac{k u_1 q \sqrt{u_2}}{\frac{1}{q^2} - \frac{1}{p^2}} \right) \epsilon^{-\beta t} \sin(q't + \phi)$$

$\sqrt{\frac{C_2}{L_1}} V_1$, a quantity of the dimensions of a current, is independent of u_1/u_2, so we get the information we require by plotting the factors inside the brackets (which are mere numbers without dimensions) against u_1/u_2. This has been done in Fig. 7. When u_1 nearly $= u_2$ there is not much difference between the ordinates of the various curves, so that at first sight one would be tempted to conclude that at resonance the response of the secondary to the primary is not much affected by the coupling. This is only apparent, however, for when the oscillation begins the principal modes are in opposition,

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and when the coupling is loose they almost cancel. As the frequencies are almost equal when k is small, it is some time before the principal modes come into phase, and then $\epsilon^{-\alpha t}$ and $\epsilon^{-\beta t}$ have diminished to such an extent that the total current is small. With loose couplings, therefore, the instantaneous value of the current is never large.

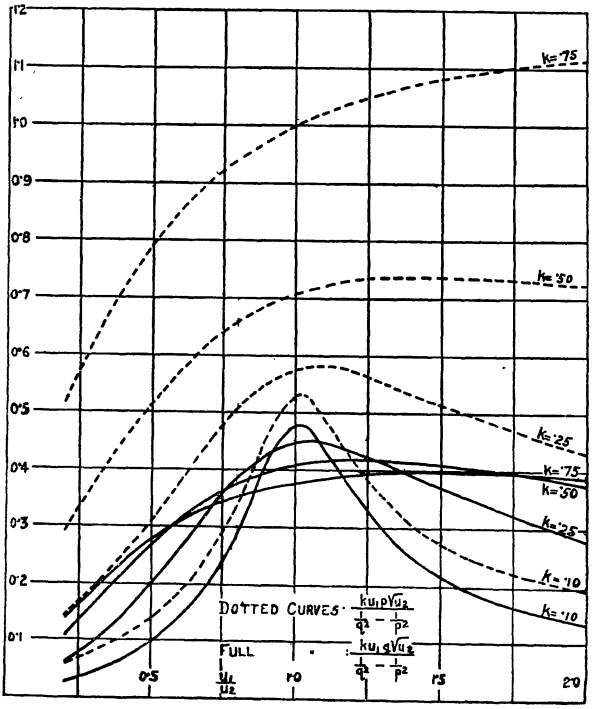

FIG. 7.

When making practical applications of the expressions we have derived, due regard must be taken to their limitations. Strictly speaking, this paper only concerns itself with the integration of a certain pair of differential equations with constant coefficients, and if the results are applied to circuits with coefficients that are functions of the time (*e.g.* circuits with spark gaps) or circuits which can only approximately be represented by concentrated resistance, inductance and capacity in series (*e.g.* antennæ and telegraph cables), nothing more than an approximate agreement with experiment is to be expected.

The method we have used can obviously be applied to circuits with electrostatic or mixed coupling; in fact, to any pair of differential equations where the damping terms are small. If the damping terms are on an equality with the others, that is in aperiodic cases, no special benefit is obtained from its use. If the un-transformed equations contain more than one cross term each, the algebra naturally becomes rather more complicated.

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The Upper Atmosphere and Radio-Telegraphy.

By THE EDITOR.

Although it has long been known that the electrical condition of the upper atmosphere has a more or less beneficial effect on long distance radio-telegraphy, results obtained during the last two or three years have shown conclusively that the effect is far more pronounced than was previously suspected. Whatever differences there have been between the results obtained by the various mathematicians who have studied the problem of the transmission of electromagnetic waves around the earth, these results have all tended to prove with a cumulative degree of certainty that the signals actually received at great distances are much stronger than can possibly be explained without calling in the aid of the upper atmosphere. Then again the variations in signal strength from hour to hour especially at sunrise and sunset indicate very conclusively that something subjected to much greater changes of electrical condition than are the earth or lower atmosphere must be concerned in the transmission. More recently the large and unexpected discrepancies which are observed in the apparent bearing of a distant fixed station have shown that the upper atmosphere plays a very important part even in the transmission over relatively short distances. When the position of a fixed station less than 200 miles away appears to change about 90° in a few minutes without any apparent cause, it is fairly obvious that the signals being received are almost, if not entirely, controlled by conditions external to the earth and to that part of the atmosphere of which we have any exact knowledge. It shows, moreover, that these conditions are subjected to rapid changes.

In the experiments with reception over long distances conducted before the war by the U.S. Navy, it was found that consistent results could be obtained only during the day, the night signals, although generally stronger, being very erratic. Similar results are obtained in direction-finding. During the day the waves come in a direct line from the transmitting station with very little trace of variation, but during the night, the direction is very variable, and the waves sometimes arrive at the receiving station by two different routes with such a phase difference that no resultant direction can be found. If the waves came with equal intensity from two directions at right-angles and had 90° phase difference they would produce a pure rotating field and the signals would be unchanged as the coil of the receiving station was rotated.

All these phenomena leave no room for doubt that the upper atmosphere plays a very important *rôle* in radio-telegraphic transmission over all but the shortest distances, but what the exact nature of this *rôle* may be is still far from clear. Near the surface of the earth the atmosphere always contains a number of free ions and the number increases rapidly as one ascends. The presence of these ions makes the atmosphere conducting, the electric current being merely the convection of these free ions in the electric field. This

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conductivity is undoubtedly very considerable at heights between ten and one hundred miles, the luminous effects known as the Aurora Borealis being associated with this conductivity. Of the constitution of the upper atmosphere little is known with certainty, but the rare gases, whatever they may be, are subjected during the day to the radiation from the sun which is undoubtedly very rich in ultra-violet energy of great ionising power. This results in the ionisation not only of the upper atmosphere, but also to a lesser extent of the lower atmosphere. Owing to the absorption of the ultra-violet energy the ionising power is gradually decreased as the light penetrates the atmosphere. There may be, however, well defined surfaces of separation between different gases, with sudden changes in the conductivity. It is generally assumed that during the night, the ionising cause having been removed, the lower atmosphere loses its conductivity and the sudden fluctuations of signal strength observed at sunset suggest that the recombination or removal of the ions takes place quickly. It is usually believed that the surface of separation between the conducting and non-conducting atmosphere recedes to a higher level and that above this the conductivity persists during the hours of darkness. At this point there are several alternative theories all more or less unsatisfactory. On meeting a sharply defined change of conductivity, the waves may be reflected just as light is reflected at a polished metal surface. The condition that the change must be sharply defined must be interpreted in terms of the wavelength, a thousandth of a millimetre in the case of light being equivalent to several kilometres in radio-telegraphy. Any difference in the results obtained with long and short waves may be due to this effect. It may be that clouds of ionisation can have as sharply defined boundaries as ordinary water clouds. If the change of conductivity is gradual the wave will pass without reflection, but will suffer absorption in the conducting medium. If the wave travels faster in the upper medium than in the lower it will gradually bend down towards the earth and thus give a result somewhat similar to that produced by reflection. The upper medium being conductive, however, the wave should travel more slowly through it than through the lower atmosphere. An ingenious suggestion in this connection was made by Dr. Eccles, namely, that the movement of the ions in the alternating electric field may be 180° out of phase with the displacement current and thus cause an apparent decrease of the specific inductive capacity. Since the velocity of wave propagation is inversely proportional to the square root of this constant of the medium, it would appear that the velocity should be greater than in free space. Many facts, however, lead us to regard the velocity of electromagnetic waves in free space as an absolutely impassable maximum, and one instinctively distrusts a theory which leads to a higher velocity. It may be that a more rigorous investigation would show that the scattering due to the absorption of energy by the ions and its re-radiation in all directions would be sufficient to counteract the effect of the apparent decrease of the specific inductive capacity.

The reflection theory is free from this difficulty and the work of Professor G. N. Watson has shown that a very slight conductivity would suffice to give the observed strength of signals over long distances. Assuming then

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that the upper atmosphere acts as a conducting reflector, what is the explanation of the difference between the day and night effects? During the night the signals are stronger but erratic in strength and direction. The increased height of the reflecting layer would tend rather to weaken than to strengthen the signals. The most reasonable suggestion is that the surface is more sharply defined by the removal of the ionisation from the lower strata when the sunlight is withdrawn. The wave is thus enabled to reach an efficient reflecting surface without passing through an absorptive medium. The irregularities in the signals at night suggest that the reflecting layer is subjected to large changes of contour. It is not easy to see, however, why the signals during the day should be so much more uniform. Is the ionisation produced by the sunlight more stable in degree and in distribution than that which persists during the night.

These are questions which we hope will be brought nearer solution by the collection and correlation of data with respect to the reception of signals at various distances from the numerous high-powered continuous wave stations.

Duplex Wireless Telephony: Some Experiments on its Application to Aircraft.

By Capt. P. P. ECKERSLEY.

(*Continued from p.* 340.)

The use of two aerials on aircraft presents some difficulty but they have been employed on American machines in the form of two single wire aerials trailed from the wing tips.

The divided earth circuit using a single aerial and two different wavelengths was extremely simple and lent itself very readily to application to aircraft. The arrangement is indicated in Fig. 3. In this diagram X represents the earth terminal of a standard type of wireless telephone transmitter, but instead of being connected directly to earth it is joined thereto through the two branch circuits L_2 C_2 and L_3 C_3. The former is tuned to the transmitter wavelength and the latter to the wavelength of the received signals. The coil L_3 is coupled to the receiver. The values of L_2 and C_2 must be adjusted so that X remains a potential node, as this reduces the tendency for current to flow through the other branch L_3 C_3. In order to prevent the power valve V_2 from generating oscillations of both the transmitter and receiver frequencies (on account of the double tuning of the aerial), it is desirable that its grid circuit L_1 should be tuned by the condenser C_1 to the frequency of the waves to be transmitted. It is better to make L_2 small and C_2 large and L_3 large and C_3 small to obtain good results. By introducing tuned stopping circuits into the two earth paths the frequency difference may be reduced to 10 per cent., whereas without stoppers it must be increased to at least 20 per cent.

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(4) PARTIAL DUPLEX.

By the use of an "augmented oscillation transmitter" in which a small steady oscillation is maintained, in combination with a receiver protected wholly from the small oscillation, but with imperfect protection for larger amplitudes, a partial duplex arrangement is possible. Such a system would represent a considerable advance over the present switch operated arrangements and should be very easy to handle.

(5) SUBSIDIARY PROBLEMS.

A number of such problems are considered in the paper, one of the most important being the question of the type of receiver to be used. In all the arrangements described above low frequency amplifiers in connection with the reaction valve were used. They have certain advantages for this type of work as they are not sensitive to feeble oscillations, and therefore it is possible to work when the receiver is not perfectly protected. Such arrangements however are not particularly sensitive and high frequency amplifiers are better, although difficulties are then experienced owing to "wipe-out" effects arising from reaction from the transmitter. The best compromise between high and low frequency amplification remains to be found by experiment.

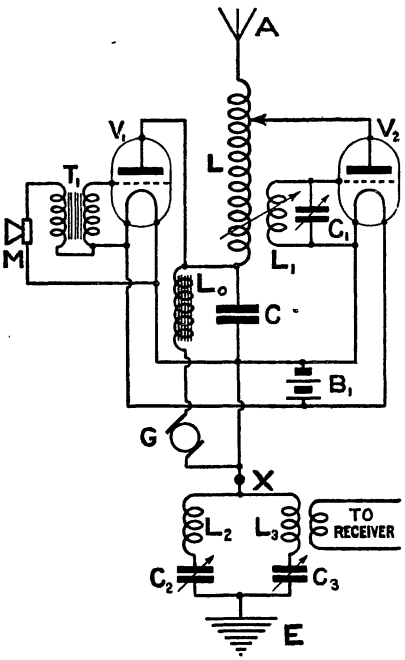

FIG. 3.

An appendix to the paper discusses the new nomenclature which has arisen in connection with this subject. This is briefly as follows :—

TRUE DUPLEX WIRELESS TELEPHONY includes all circuits which protect the receiver from the most intense oscillations generated by the transmitter, so that "chipping in" is always possible.

PARTIAL DUPLEX WIRELESS TELEPHONY includes circuits in which the receiver is protected from a small permanent oscillation generated in the transmitter, this oscillation being increased in value when speaking, proportionately with the intensity of the voice. With this arrangement "chipping in" is not always possible.

AUTOMATIC DUPLEX WIRELESS TELEPHONY includes circuits in which the transmitter only produces oscillations when speaking, which automatically paralyse the receiver meanwhile so that the system resembles only an automatic switching system.

Any type of transmitter can be used with true duplex telephony. The name AUGMENTED OSCILLATION TRANSMITTER has been given to the transmitter used with partial duplex systems; and the name QUIESCENT AERIAL TRANSMITTER has been given to the one used with the automatic duplex system.

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In the discussion attention was drawn to the advantages which had undoubtedly accrued owing to the great number of brilliant young scientists who had been led by the necessities of the war to concentrate their energies on problems connected with radio-telegraphy and telephony. It required considerable optimism to attempt to obtain good speech by means of the quiescent aerial systems described in the paper. Contrary to the impression gathered from a perusal of the technical journals of other countries since the armistice, it is made abundantly clear by this paper, and by the other papers recently read before the Institution, that research work of the highest order was carried out in this country and that in the design and application of wireless apparatus to meet the novel conditions continually arising, the scientific workers attached to the various branches of the services were second to none.

Harmonics in C.W. Transmission.*

By Capt. L. A. T. BROADWOOD, A.M.I.E.E.

This paper summarised the results of some experiments carried out in France in December, 1916, on C.W. Transmitters. They were fundamentally concerned with measuring the efficiency of the transmitter, by determining the effective resistance of the aerial using a substitution dummy aerial circuit. The aerial capacity was measured by means of a charge-and-discharge commutator and the dummy aerial capacity given the value determined in this way. The effective resistance of the aerial was then determined at various wavelengths by adjusting the resistance of the dummy circuit until the same current was obtained as in the actual aerial. The curve of resistance was found to exhibit peaks at various wavelengths which were exact multiples of the fundamental wavelength of the aerial, and the efficiency curve likewise showed similar peaks (Fig. 1).

The paper concluded with a graphical construction for obtaining the waveform of the plate current from the static characteristic of the oscillating tube. The wave was found to be flat-topped and unsymmetrical for the case considered in the paper. The harmonics in the plate current, which in the direct-coupled transmitter flow through the aerial tuning inductance, excite the natural harmonics which are found in the aerial circuit itself by reason of its distributed capacity and inductance.

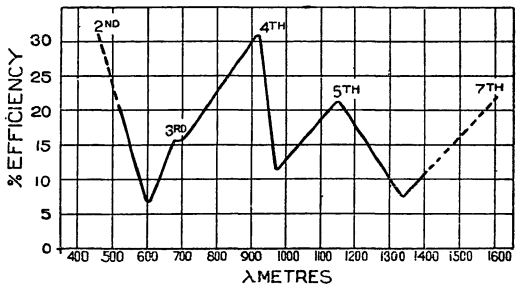

FIG. 1.

In the discussion a simple method was described for detecting the presence of an unsymmetrical wave in the transmitter, by coupling it to a tuned wavemeter circuit across which was shunted a crystal detector and galvanometer. By reversing the coupling a different deflection will be obtained on the galvanometer if the waveform is unsymmetrical.

* Paper read before the Wireless Society of London on March 26th, 1920.

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Review of Radio Literature.

1. Articles and Patents.

325. THEORETICAL INVESTIGATION OF THE RADIATION FROM ANTENNA SYSTEMS. M. Abraham. (*Archiv für Elektrotechnik*, 8, p. 92, 1919.)

A study of the radiation from two neighbouring antennæ oscillating in synchronism and of the effect on the radiation resistance and frequency of each due to the other with various degrees of coupling. A study of the effect both in sending and receiving antennæ of erecting in the neighbourhood an auxiliary unexcited but tuned antenna, which by its absorption and radiation produces screening and reflection effects.

See also RADIO REVIEW Abstract No. 91.

326. THE ELECTRO-DYNAMICS OF RADIATION CIRCUITS. K. W. Wagner. (*Archiv für Elektrotechnik*, 8, p. 145, 1919.)

This is mainly concerned with arrangements of inductances, capacities and resistances to produce an artificial aerial.

327. AN INVESTIGATION OF SO-CALLED QUENCHED SPARKS. V. Pieck. (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 40—67, January, 1920. See also *Göttinger Diss. and Annalen*, 54, p. 197, 1917. *Technical Review*, 6, p. 225, March 2nd, 1920.)

An experimental investigation of the effect on the quenching phenomenon of the material of the electrodes, of the nature of the gas and of its pressure, of the shape of the electrodes, of the frequency and of the amplitude of the current. This is followed by a theoretical study of the phenomenon of quenching, following the theory of Roschansky. The spark is treated as an electric arc and oscillograph records are given of low frequency arc phenomena. It is shown that the spark discharge can be completely explained in this manner.

328. THE MANDELSTAM METHOD OF ABSOLUTE MEASUREMENT OF FREQUENCY OF ELECTRICAL OSCILLATIONS. J. Tykocinski-Tykociner. (*Philosophical Magazine*, 39, pp. 289-294, March, 1920.)

Describes the method used for calibrating wavemeters devised by Dr. Mandelstam of the Russian Siemens and Halske Works in Petrograd. A buzzer B (Fig. 1) excites an aperiodic circuit (a) thus providing a source of oscillations of a wide range of frequencies owing to the non-sinusoidal character of the current waveform. Oscillations, the frequencies of which are exact multiples of the buzzer frequency have the largest amplitudes. The circuit (b) the frequency of which is to be measured is coupled with the

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aperiodic circuit and also with the detector circuit (c) which is used for indicating resonance in (b). If n is the interrupter frequency and s the number of maxima observed between two settings of the condenser C_2, corresponding

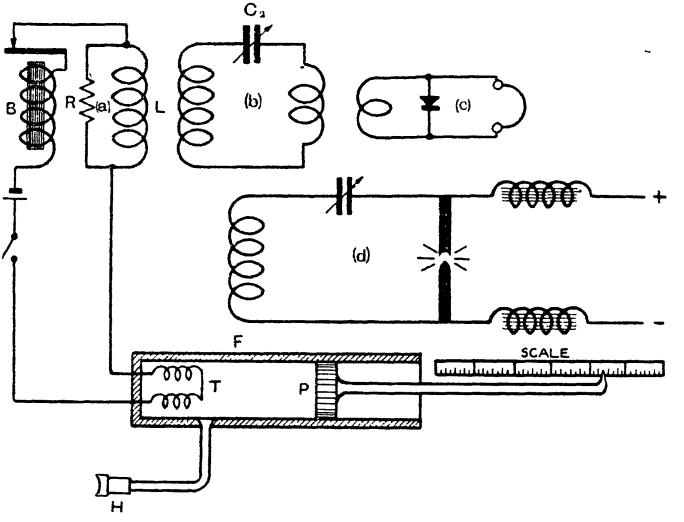

FIG. 1.

to natural frequencies ν_2 and ν_1 of circuit (b) it is shown that

$$\nu_1 = s \cdot n \frac{1}{\left(\frac{\nu_2}{\nu_1} - 1\right)}$$

Thus the frequency for one setting of C_2 can be determined if $\frac{\nu_2}{\nu_1}$ is known.

It is found most convenient to make $\frac{\nu_2}{\nu_1}$ a whole number. This is done by adjusting a continuous wave generator (d)—arc or triode—so that ν_1 and ν_2 are the frequencies of known harmonics of the generator. The interrupter frequency is determined by measuring the wavelength of the sound wave emitted by a telephone T in the circuit. The telephone is fixed at the end of a tube F and the positions of the piston P for maximum sound intensity in the earpiece H are determined, from which the wavelength can be found. An accuracy of 0·5 per cent. is claimed.

329. THE CALCULATION OF THE SELF-INDUCTANCE OF MULTI-LAYER COILS. A. Esau. (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 2—26, January, 1920.)

Unlike previous methods this is not based on the assumption of a uniform current distribution over the whole space occupied by the coil, but upon the

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self and mutual inductance of the several turns. The result is expressed in the form of $L = 4\pi rmn(S_1 + S_2)$ for a coil of m layers, each of n turns, and of mean radius r. S_1 and S_2 are complicated functions of r, m, n, the radius of the wires and the pitch of the turns. Tables and curves are given whereby S_1 and S_2 can be determined with sufficient accuracy for all practical purposes. With the help of numerical examples the new formula is compared with the previously known approximate formulæ of Maxwell, Perry, Weinstein and Stefan.

330. EXPERIMENTS WITH LOOP ANTENNÆ. C. L. Whitney. (*Radio Amateur News*, 1, p. 283, December, 1919.)

The experiments were carried out aboard ship about 600 miles from Nauen. Various shaped loops were tested, and best results were obtained on a triangular loop with apex vertical about 40 feet above the deck and with both ends earthed.

331. MEASUREMENT AND COMPARISON OF SIGNAL INTENSITIES IN WIRELESS RECEIVERS. H. de Bellescize. (*Revue Générale de l'Électricité*, 7, pp. 325-328, March 7th, 1920.)

A method of comparing the intensity of the signals from a distant continuous wave station with those of a local calibrated triode emitter is described. The local source is wholly enclosed in a Faraday cage F_1 (Fig. 2) with the exception of the coil J (of variable self-inductance) which is included in the oscillatory circuit of the triode emitter. The effect of J on the receiver

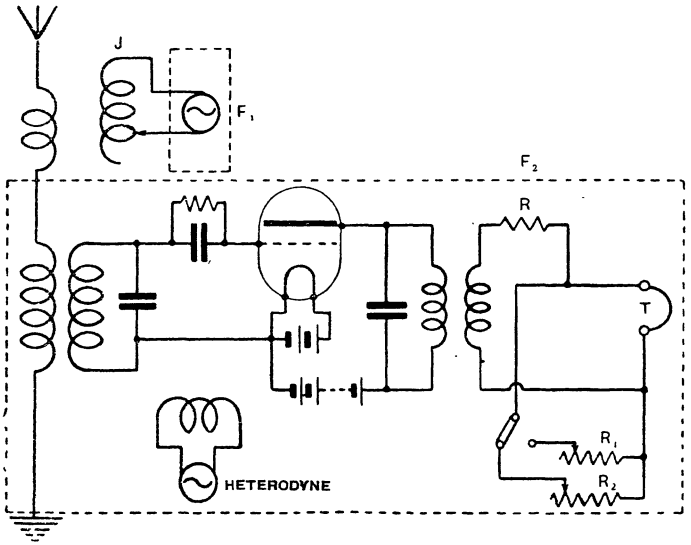

FIG. 2.

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is proportional to the current I through the coil (I is found to be approximately proportional to the anode battery voltage).

A chronographic arrangement for alternating the signals of the distant station and of the local station (each being heard ten seconds at a time) is used. The final adjustment to equality is not made by altering the value of I but by means of non-inductive shunts R_1 and R_2 across the telephones T. If the values of these two shunts for the two cases of distant and local signals are respectively R_1 and R_2 and N is the number of turns of the coil J included in the oscillatory circuit of the local emitter, then the signal intensity I_x is given by $\kappa INR_2/R_1$ where κ is approximately constant. The resistance R is of the order of 2,000 ohms so that the variations of R_1 and R_2 make little variation in the total resistance of the telephone circuit. To reduce as much as possible the effect of external disturbances the receiver is enclosed in an earthed cage F_2.

A method of determining the amplifying power of any triode arrangement is described, the intensities of the signals being determined with and without the amplifying assembly included.

332. IMPROVEMENTS RELATING TO RADIOTELEGRAPHIC TRANSMITTERS. A. Taylor. (*British Patent* 135111, April 4th, 1919. Patent accepted, November 20th, 1919.)

In connection with the well-known method of controlling the output from an arc transmitter by short-circuiting with the sending key a loop of wire inductively coupled to the aerial circuit,* provision is made in the case of high power stations for the splitting up of this loop into a number of separate segments each arranged to be short-circuited by electromagnetically operated keys. For obtaining a definite group frequency for the transmitted waves interrupters may be connected in series or shunt with each pair of relay contacts.

333. TRANSMITTERS. A. Taylor. (*French Patent* 497798, April 3rd, 1919. Published December 17th, 1919.)

The specification describes a system of radiotelegraphic transmission. For further particulars, see British Patent No. 136059.†

334. RADIOTELEGRAPHIC TRANSMISSION SYSTEMS. A. Taylor. (*British Patent* 136059, March 25th, 1919. Patent accepted, December 11th, 1919.)

In a system of wireless signalling the emission of radiation from the aerial is controlled by an auxiliary circuit. In Fig. 3 the aerial is supplied by the arc A_1 fed from the D.C. generator G. The auxiliary circuit includes the condenser C, the inductance L and a winding L_1 on an iron core T. This iron

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* *Cf.* RADIO REVIEW Abstracts Nos. 114, 189.

† RADIO REVIEW Abstract No. 334.

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core is also provided with a second winding L_2 through which direct current flows when the signalling key K is in the position of rest. This current is arranged to saturate the iron core and oscillations will then take place in the

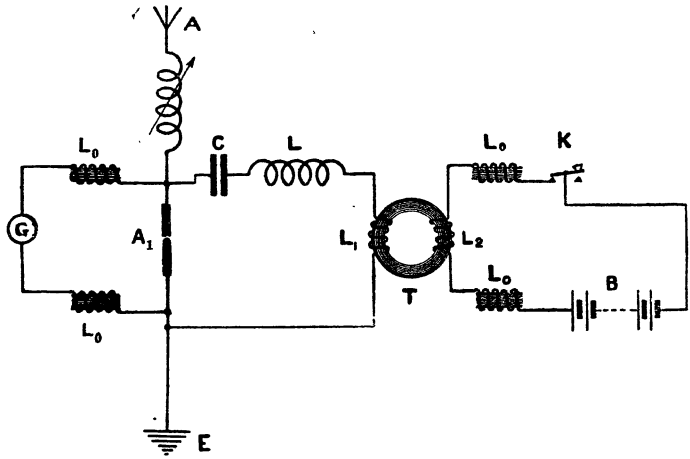

FIG. 3.

auxiliary circuit C L L_1 to the exclusion of the aerial circuit. When the key is pressed the direct current is interrupted and the large hysteresis loss which then occurs in the iron core chokes back the high frequency current from the auxiliary circuit. Choke coils L_0 may be inserted in the direct current circuit to prevent the flow of high frequency current in that circuit. The iron core may be water or oil cooled.

335. CONTINUOUS WAVE TRANSMITTERS. L. F. Fuller. (*French Patent* 496096, February 21st, 1919. Published October 25th, 1919.)

The invention described in this specification consists of an oscillation generator of the arc type. A cathode, for example of carbon, and an anode of less width than the cathode are both enclosed in a casing so that the arc may be produced in an atmosphere of hydrogen, and the poles of a magnet extend into the said casing to produce a magnetic flux in the gap between the anode and the cathode. The distance between the anode and the poles is greater than the distance between the cathode and the poles, and is also greater than the distance between the anode and the cathode.

336. INDUCTOR ALTERNATORS. E. F. W. Alexanderson. (*British Patent* 134830, October 28th, 1919. Convention date November 4th, 1918. Patent not yet accepted but open to inspection.)

Special constructional details for the inductor of an Alexanderson type

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high-frequency alternator are described in this patent. Two circumferential rows of radial slots filled with non-magnetic material are provided for.

337. IMPROVEMENTS IN FREQUENCY TRANSFORMATION. General Electric Company, U.S.A. (*British Patent* 134045, October, 1918. Patent accepted, October 29th, 1919.)

A radiotelephone transmitter is described using a high-frequency alternator as the source of oscillations. In Fig. 4, the current from the alternator G is deformed by the coil L_3 so that a higher harmonic may be used in the aerial

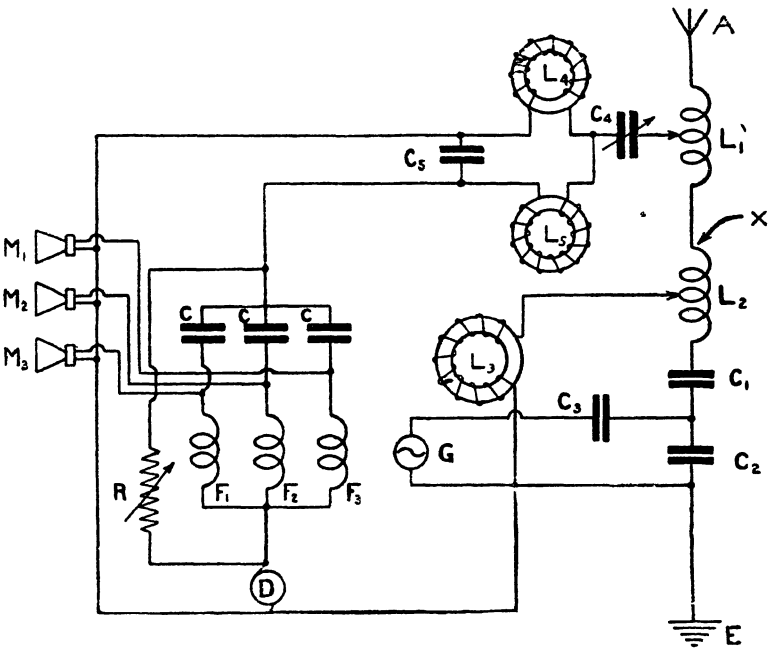

FIG. 4.

circuit. The condenser C_3 compensates for the internal inductance of the alternator G. Condenser C_2 compensates for the inductance of coil L_3, and condenser C_1 for that of L_2. In order to prevent current of fundamental frequency flowing in the aerial circuit the upper point X of the coil L_2 is arranged to be approximately at earth potential. The aerial circuit is tuned to the higher harmonic. For controlling the amplitude of the continuous wave radiation, multiple microphones M_1 M_2 M_3 (all under the influence of a single mouthpiece) are arranged as shown to modify the magnetic saturation of the iron core inductances L_4 L_5 which are supplied from the direct current generator D. These two inductances therefore act as a variable shunt to the aerial circuit. Condenser C_5 is arranged to offer a low impedance to the

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high-frequency currents. F_1 F_2 F_3 represent the divided field windings of the alternator G and serve mainly as steadying inductances in series with the microphones.

338. THE MODULATION OF HIGH-FREQUENCY OSCILLATIONS. Western Electric Company, U.S.A. (*British Patent* 133366, June, 1918. Patent accepted, October 16th, 1919.)

A wireless telephone transmitter is arranged so that the modulation current from the microphone M (Fig. 5) is amplified by the valve V_1 which

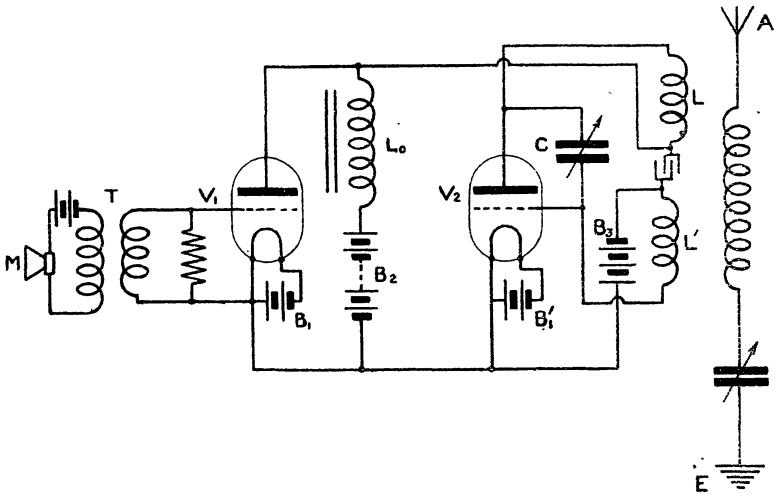

FIG. 5.

is joined across the high tension battery B_2 and the choke inductance L_0 which form part of the plate circuit of the oscillation generating valve V_2. The voltage supply to the plate circuit of the generating valve V_2 is thus varied in accordance with the speech signals from M. The circuits of V_2 for generating the oscillations may be arranged in the well-known manner indicated—L L' C being the oscillation circuit.

339. LIQUID MICROPHONES. S. G. Brown. (*British Patent* 134865, August 13th, 1918. Patent accepted, November 13th, 1919.)

In one form of the liquid microphone described in this specification, the containing vessel is divided horizontally into two portions by an insulating barrier. The centre of this insulating partition is pierced with a small hole over which a valve is arranged in such a manner that the effective opening between the two parts of the containing vessel is varied by the motion of the diaphragm to which the valve is coupled. In Fig. 6, A is the containing vessel, D the diaphragm, B the insulating partition, H the small hole through

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this partition and V the valve connected as shown to the diaphragm, D. E_1 and E_2 are the two electrodes of the microphone. Other modifications are described in the original—in one of these the diaphragm forms one wall of a narrow passage through which the electrolyte passes, so that its effective cross sectional area is varied by the motion of the diaphragm.

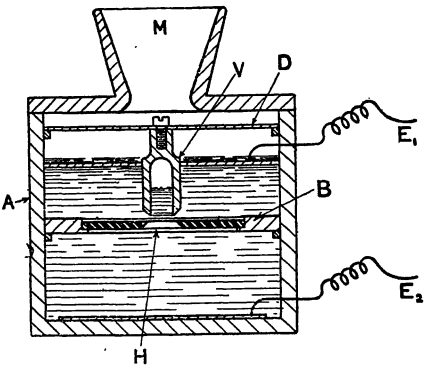

FIG. 6.

340. APPARATUS FOR CONTROLLING ELECTRICAL ENERGY IN SIGNALLING SYSTEMS. C. D. Ehret. (*British Patent* 134725, February 20th, 1919. Patent accepted, November 13th, 1919.)

One of the arrangements described is illustrated diagrammatically in Fig. 7. The microphone M is arranged to control the output of the valve

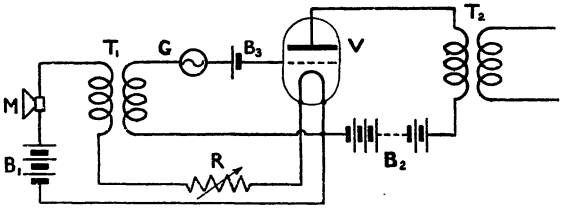

FIG. 7.

amplifier V by controlling simultaneously its grid potential (through the transformer T_1) and its filament current. In the arrangement indicated no reaction is provided between the plate and grid circuits in order to cause the valves to set up oscillations, but a source of high frequency fluctuating or alternating current is impressed upon the grid circuit at G. Various other modifications of this idea are described, including a very similar arrangement suitable for use when reaction coupling in the valve is employed.

341. TELEPHONE TRANSMITTERS. E. S. Pridham and P. L. Jensen. (*British Patent* 133365, June, 1918. Patent accepted, October 16th, 1919.)

Telephone transmitters for use on aeroplanes and in other noisy situations have their diaphragm exposed on both sides to the noise vibrations, whereas the speech vibrations act only on one side. By suitably adjusting the distance between the instrument and the speaker's mouth the effect of the undesired noises may be reduced to a minimum.

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342. TELEPHONE TRANSMITTERS. A. Marr. (*British Patent* 133527, November 1918. Patent accepted, October 16th, 1919.)

The constructional features are described of a telephone transmitter in which the vibrations of the diaphragm are transmitted to the movable electrode of the microphone through a confined layer of air.

343. TELEPHONE TRANSMITTERS. E. M. C. Tigerstedt. (*British Patent* 135183, November 10th, 1919. Convention date November 8th, 1918. Patent not yet accepted but open to inspection.)

In one of the forms of microphone transmitter described, the electrodes are in the form of circular discs between which are placed layers of insulating cloth. The discs are connected alternately to the two terminals of the instrument. The edges of the disc are surrounded by a thin layer of granular microphonic material held against the electrodes by a flexible covering which is operated upon by the speech waves, so as to vary the pressure upon the granules. Other modifications are described, for example one in which the electrodes are in the form of annular rings separated from one another by the insulating cloth and with the layer of granules pressing against one set of edges of the rings.

344. TELEPHONE TRANSMITTERS AND RECEIVERS. Western Electric Company, U.S.A. (*British Patent* 134872, September 20th, 1918. Patent accepted, November 13th, 1919.)

In order to increase the natural period of vibration of the diaphragm of a telephone transmitter or receiver, or of similar acoustic apparatus, a broad flat surface is rigidly mounted at a distance of not more than $2\frac{1}{2}$ mils. (0·0025 inches) behind the vibrating diaphragm. The layer of air between the diaphragm and the flat surface increases the damping of the diaphragm.

345. WIRELESS TELEPHONY. A. Meissner. (*Telegraphen- und Fernsprech-Technik*, 8, pp. 45—48, July, 1919.)

A brief review of the subject, more especially of methods used by the Telefunken Company. As generators of the high-frequency current alternators can be used for large powers and large wavelengths, arcs and valves for medium and small powers. The arc can only be used for waves above 2,000 metres. The future belongs to the thermionic valve. The precautions necessary to make a number of microphones work in parallel are described. The microphone current can be made to affect the iron of the frequency doubling transformers inserted between the alternator and the aerial (diagram given in original). Two methods of using thermionic generators are described, one suitable for small powers with the microphone in the aerial, and the

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other for large powers with the microphone acting on the grid. A three valve amplifier is shown for insertion between the receiving end of a telephone line and the control of the wireless transmitter. Two-way working by means of two separated aerials tuned to slightly different frequencies is discussed.

346. IMPROVEMENTS CONNECTED WITH THE VALVES OF WIRELESS TRANSMISSION SYSTEMS. C. E. Hiatt. (*British Patent* 131668, July, 1918. Patent accepted, September 4th, 1919.)

A special arrangement of spring is described for maintaining the tension on the filaments of valves. The spring is constructed of platinum-coated nickel steel and should be freed from gas in the same manner as the other parts of the valve.

347. IMPROVEMENTS RELATING TO THE MANUFACTURE OF ELECTRICAL VALVE TUBES. L. Robinovitch. (*British Patent* 131670, July, 1918. Patent accepted, September 4th, 1919.)

To improve the vacuum some or all of the metal parts are provided with a film of oxide or other compound with the metal of which the parts are constructed, or with a film of gas capable of chemical combination with such parts. The plate or grid may, for instance, be heated in oxygen, dry air, chlorine, sulphur dioxide, or it may be electrolytically coated with a film of oxygen in dilute acid or with chlorine in brine. After sealing off the tube, the anode is again brought to a dull red heat for a few seconds. Prolonged ageing to remove the residual gas is unnecessary.

348. VACUUM TUBES. C. E. Hiatt. (*British Patent*, 133181, October, 1918. Patent accepted, October 9th, 1919.)

The grid and anode of a vacuum tube for use in wireless consist of wires stretched across the tube and anchored into the walls by fusion of the glass.

349. THE CONSTRUCTION OF VACUUM TUBES. R. S. Hawkins. (*Radio Amateur News*, 1, pp. 278—279, December, 1919.)

A general description of the manufacturing methods of vacuum tubes particularly of the Moorehead Tube.

350. IMPROVEMENTS IN ELECTRICAL DISCHARGE DEVICES. Cutler-Hammer Manufacturing Company, U.S.A. (*British Patent* 133783, October 1918. Patent accepted, October 17th, 1919.)

This patent deals with a particular construction of three-electrode vacuum tube with double flat anodes. The grid electrode consists of a fine wire

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closely wound over two transverse springs mounted in the plane of the filament, the grid wires being held out on each side of the filament by one or more flexible transverse wire bridges. The grid wire should be fine and closely wound.

351. IMPROVEMENTS IN THREE-ELECTRODE VACUUM TUBES. J. Erskine-Murray. (*British Patent* 133413, October, 1918. Patent accepted, October 6th, 1919.)

The particular feature of the valve described is the arrangement of the position of the grid electrode, so that an increase in its potential causes a decrease in the current passing between the anode and cathode, and *vice versa*.

352. OSCILLATION CHARACTERISTICS OF THREE-ELECTRODE LAMPS USED AS GENERATORS OF SUSTAINED OSCILLATIONS. A. Blondel. (*Comptes Rendus*, 169, pp. 676—680, October, 1919.)

The ordinary method of studying the oscillations set up by 3-electrode valves based on a consideration of the straight part of the characteristics does not take into account the limitation of the amplitude of the oscillations by the curvature of the characteristics. The author shows that a more general method of treatment may be based upon the "oscillation characteristics" of the valve, and it is shown how the ordinary static curves may be transformed graphically to give the dynamic curves. These curves are preferably plotted with plate current as abscissæ and plate voltage as ordinates thus resembling the dynamic characteristics of oscillating arcs.

If U_1 = the normal plate voltage without oscillations,
V_1 = the normal grid voltage without oscillations,
I_1 = the normal plate current without oscillations,

these three values determine the co-ordinates of one point upon the complete system of curves for the valve. If then the establishment of oscillations causes a variation i in the plate current (this variation being approximately sinusoidal), there will be a corresponding variation u in the potential at the terminals of the plate circuit. By reason of the reaction provided between the plate and grid circuits this change u will give rise to a voltage variation v which will be superimposed upon the steady voltage V in the grid circuit. Hence a new point upon the "oscillation characteristic" has co-ordinates of $(I_1 + i)$, $(V_1 + v)$, and $(U + u)$. By giving various values to i throughout the cycle, the complete curve may be delineated.

Three cases are considered in the paper:—

I. Inductive coupling, for which $v = -au = -(M/L)u$ where M = the mutual inductance between plate and grid circuits and L = inductance in plate circuit, at the terminals of which the voltage variation u takes place—assuming that the resistance of L is negligible. a = a constant of proportionality = M/L in this case.

II. Resistance or "potentiometric" coupling in which the grid voltage is

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derived from the change in p.d. at the terminals of a resistance in the plate circuit.*

For this case $v = + bi$, where b is some constant.

III. The general case for which $v = \phi(u, i)$ including the special case which combines I. and II. for which the function ϕ is linear—viz., $v = + au + bi$.

353. THEORY OF THE OPERATION OF THE AUDION DETECTOR. F. Carbenay. (*Revue Générale de l'Électricité*, 6, pp. 579—583, November, 1919.)

A mathematical article dealing particularly with the use of a triode valve as a detector of high-frequency oscillations. The sections covered by the paper are as follows :—

(1) The semi-empirical equations of the valve.
(2) Arrangement of audion detector and equation of the grid potential.
(3) Reception of trains of sustained waves.
(4) Reception of wave trains of any type.
(5) The use of an auxiliary oscillation generator (heterodyne).
(6) Low-frequency power output in the plate circuit.
(7) The response (output) of the audion detector.

354. A SIMPLIFIED THEORY OF THE VALVE AMPLIFIER. E. Mallett. (*Post Office Electrical Engineers' Journal*, 12, pp. 134—137, October, 1919.)

The theory given is based on the assumptions that over the range used, the plate current—grid voltage, and plate current—plate voltage curves, are straight lines. The author then shows that the total change in plate current is the sum of the changes due to the voltage impressed on the grid and to the consequent changes in plate voltage. Hence the voltage amplification is $\frac{\mu Z}{R_0 + Z}$, where $\mu = \frac{\tan \theta}{\tan \phi} = \frac{\text{slope of grid voltage—plate current curve}}{\text{slope of plate voltage—plate current curve}}$, R_0 = the internal impedance of the valve, and Z = external plate-circuit impedance.

355. THE DESIGN OF MULTIPLE-STAGE AMPLIFIERS. C. L. Fortescue. (*Electrical Review*, 85, pp. 700—701, November 1919.)

See RADIO REVIEW, 1, pp. 83—88, 134—143.

356. THE MEETING OF THE BRITISH ASSOCIATION : DISCUSSION ON THERMIONIC VALVES. (*Electrician*, 83, pp. 306—307. *Electrical Review*, 85, pp. 380—382, September, 1919. *Engineering*, 128, p. 357, Abstract. *Radio Review*, 1, p. 26—38, October, 1919.)

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* See also RADIO REVIEW Abstracts Nos. 236 and 237.

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357. Triode Amplifications and Detector Sensitivity. A. Press. (*Electrician*, 84, pp. 35—36, January 9th, 1920.)

This article is designed to remove the confusion between the formulæ used by L. B. Turner* and those employed in discussions at the Institute of Radio Engineers. Formulæ for the potential and current magnifications, and for the detector sensitivity, are evolved from the relation $i_a = f(v_a, v_g)$. [i_a = anode current, v_a = anode voltage, and v_g = grid voltage.] It is shown that the potential magnification is given by

$$\frac{dv_a}{dv} = \frac{-R_g}{1+R/\Omega} = -\frac{R\frac{\partial i_a}{\partial v_g}}{1+R\frac{\partial i_a}{\partial v_a}}$$

where R = resistance in anode circuit, R_g = resistance in grid circuit, and $\frac{1}{\Omega} = \partial i_a/\partial v_a$ = the internal plate-filament conductance determined with v_g constant. The current amplification is given by $\frac{di_a}{di_g} = \frac{g\omega}{1+R/\Omega - R\omega g g'}$, where ω = the internal grid-filament resistance determined with v_a constant, $g = \partial i_a/\partial v_g$ = mutual conductance, and $g' = \partial i_g/\partial v_a$ = the conjugate mutual conductance, and is much smaller than g. The detector sensitivity, $G = di_a/dv_g = -\frac{R_g}{\Omega}\cdot\frac{1}{1+R/\Omega} + g = \frac{g}{1+R/\Omega}$.

358. Waveform obtained from the Aluminium Rectifier. N. H. Williams and J. M. Cork. (*Electrical World*, 74, pp. 937—938, November, 1919.)

The use of several rectifying cells in series, to enable voltages up to 2,200 to be rectified, is dealt with in this article. Some oscillograms are given of the waveforms of the voltage and current showing the smoothing effect of capacity in parallel with the D.C. load, and of inductance in series with the load. The special arrangement of double rectifier and smoothing condenser indicated in Fig. 8 is also described. This arrangement is attributed to Schultz and it enables D.C. voltages to be obtained up to about two and a half times the R.M.S. alternating voltage.†

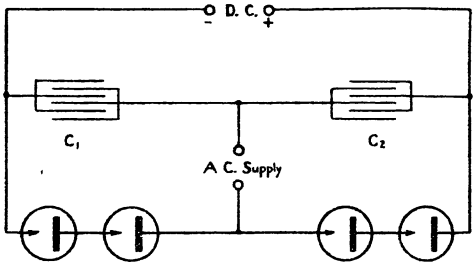

Fig. 8.

* *Electrician*, 83, pp. 4—5, 34—35, July 4th and 11th, 1919.

† An analogous arrangement using valve rectifiers was described in Radio Review Abstract No. 119.

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359. WIRELESS DIRECTION FINDING. N. P. Hinton. (*British Patent* 134644, November 22nd, 1918. Patent accepted, November 13th, 1919.)

The direction of a wireless transmitting station is determined by employing three, five, or more immovable directive aerials and comparing signals received when the aerials are connected in series in various orders, or when the aerials are placed in circuit singly in turn. The arrangement particularly described has three aerial systems crossing one another at angles of 60°. These may either be joined up in series in various combinations or any one of the three may be connected in turn to the receiving apparatus. The circuit of the three aerials is completed through the movable coil of a special type of radiogoniometer having the same number and arrangement of fixed windings as there are receiving aerial systems. These fixed windings are connected to the receiver proper, and they are arranged in the same combination as are the external aerials. The change over of the connections for the various combinations is effected simultaneously for the aerial systems and for the radiogoniometer coils. In taking a reading of direction the two aerials which give the loudest signals are used and the connections are changed over from one to the other while the position of the radiogoniometer search coil is adjusted until equal intensity of signal strength is obtained in the two positions. The pointer attached to the moving coil then indicates the direction of the waves.

360. THE U.S. NAVY RADIO COMPASS. (*Everyday Engineering Magazine*, 8, pp. 109—111, November, 1919.)

This article describes in general terms the directive action of a loop aerial, and then gives the combined antenna and loop aerial arrangement used to obtain the absolute direction instead of two alternative directions as given by the simple loop. In Fig. 9 A_1 is an ordinary elevated aerial and A_2 is a frame aerial inserted in the tuned secondary circuit coupled to A_1. V is

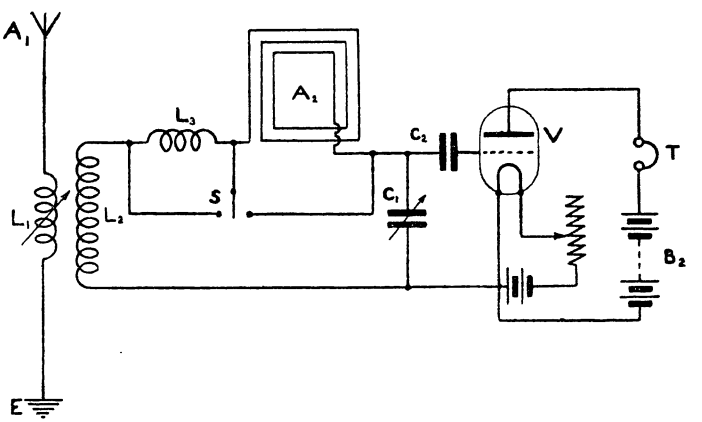

FIG. 9.

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any usual form of valve detector. The inductance L_3 is made equal to that of A_2, so that the wavelength of the circuit L_2 C_1 remains unchanged when the loop is cut out of this circuit by the switch S. Signals are first picked up on A_1 and carefully tuned with A_2 cut out. The loop A_2 is then inserted in the circuit, and the absolute direction determined approximately. The ordinary aerial A_1 is then cut out and the directional line of the incoming waves determined exactly, using the sharper minimum positions on the receiving loop. Further details are to follow in a subsequent article.

361. HOW AEROPLANES ARE NAVIGATED BY WIRELESS. R. Keen, (*Wireless World*, 7, pp. 389—393, October, 1919.)

An elementary description of the use of the radiogoniometer, and of D.F. working between aircraft and ground stations.

362. ON THE GONIOMETRIC FUNCTIONS APPLICABLE TO DIRECTIVE AERIALS. A. E. Blondel. (*Radio Review*, 1, pp. 1—10; 58—66; 110—123, 1919.)

363. THE TRANSMISSION OF ELECTROMAGNETIC WAVES AROUND THE EARTH. G. W. O. Howe. (*Radio Review*, 1, pp. 78—80, November, 1919.)

364. RADIOTELEGRAPHIC INVESTIGATIONS—REPORT OF BRITISH ASSOCIATION COMMITTEE. (*Electrician*, 83, pp. 311—312, September, 1919. *Radio Review*, 1, pp. 24—26, October, 1919.)

365. THERMIONIC AMPLIFIERS. Siemens and Halske, Akt.-Ges. (*British Patent* 134832, October 30th, 1919. Convention date May 22nd, 1918. Patent not yet accepted but open to inspection.)

When several amplifying valves are used to form a cascade amplifier with the filaments connected in series, provision is made for suitably determining the grid potential of each valve by connecting the grids to different points on the common filament battery, or to different points on a potentiometer resistance shunted across that battery.

366. REMARKABLE AMPLIFICATION. (*Scientific American*, 121, p. 457, November, 1919.)

Mentions the use of 19-stage multivalve amplifiers by the British Navy for intercepting buzzer signals over long distances.

367. IMPROVEMENTS RELATING TO AMPLIFYING APPARATUS. M. Latour. (*British Patent* 132668, November, 1917. Patent accepted, September 25th, 1919.)

An addition to British Patent No. 130103. In the multivalve amplifier

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described, the plate circuits are supplied from a common high tension source B_2 (Fig. 10) and two of the valves are used for amplifying both the high and the low-frequency currents. The incoming signal is supplied to terminals T, T and is amplified by the valves V_1, V_2, V_3 which are connected together through high-frequency transformers T_1, T_2. V_4 serves as a detector and its low-frequency output circuit is joined in series with the grid circuit of valve V_2 through low-frequency transformer T_5 and the secondary winding of T_1 as indicated. The low-frequency current is thus further amplified by V_2 and V_3 coupled by the low-frequency intervalve transformer T_3, and finally led to terminals T', T'. The windings of T_3 are shunted by condensers as shown in order to provide a bye-path for the high-frequency currents which are passed from V_2 to V_3 through the high-frequency transformer T_2.

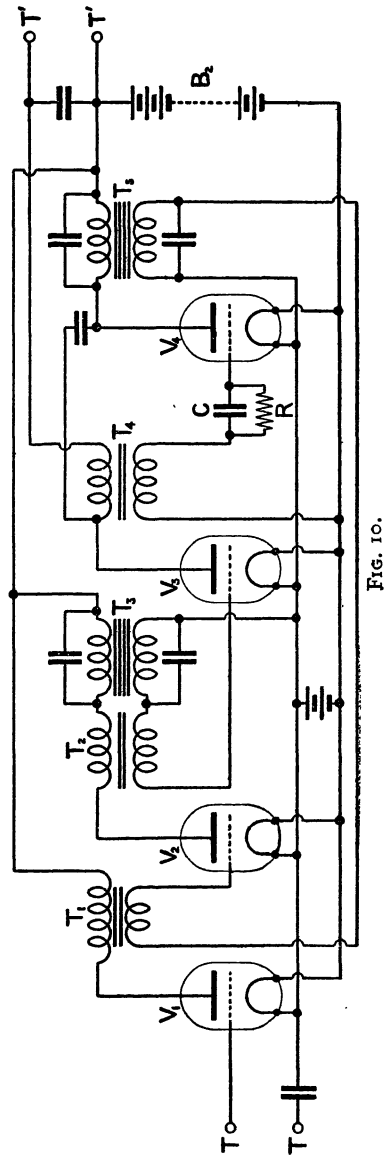

FIG. 10.

368. A THERMIONIC AMPLIFIER FOR LOW-ANODE VOLTAGES. E. Rüchardt. (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 27—39, January, 1920. *Technical Review*, 6, p. 225, March 2nd, 1920.)

A record of some extremely interesting experiments carried out at Würzburg under the direction of W. Wien for the Army and Navy authorities, with the object of designing an amplifier which would operate with an anode voltage of 10 volts or less. In one form the filament is placed between two parallel plates about 2 mm. apart one acting as anode and the other as grid. With an anode voltage of 10 the steepness of the characteristic was only 0·6 of that of a normal 90 volt amplifier and gave only 0·4 to 0·5 of the amplification. Attempts to bring the control electrode nearer the filament introduced difficulties owing to the distances changing when the supports became heated. This led

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to several new types of construction being tried. Fig. 11 represents the form finally adopted; the filament is held taut between two springs of coppered steel wire which act as leads. The anode and control plate are angle plates carried on the glass stem. In Fig. 12, curve 1

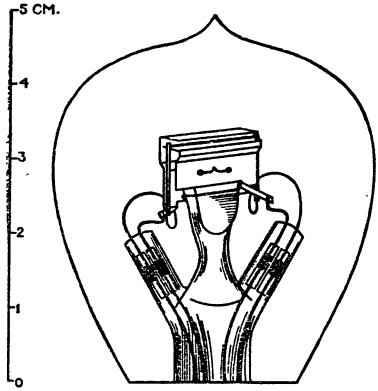

FIG. 11.

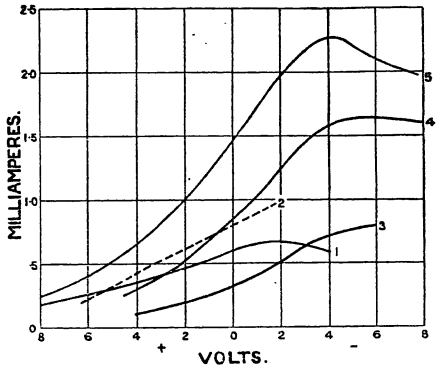

FIG. 12.

refers to the earlier type mentioned above, curve 2 (dotted) shows the normal steepness of a 90 volt amplifier and curves 3, 4 and 5 are the characteristics of the new type at voltages of 6·5, 13 and 20 volts respectively. Many of the troubles were traced to bad tungsten filaments and were overcome by using the so-called crystal wire made by Pintsch. With inferior filaments good results were only obtained by overrunning the filament.

The steepness of the characteristic is greater than in the 90 volt case, in one case three times as steep, but the internal resistance is much lower, viz., about a tenth, that is $\partial I_a/\partial E_g$ is greater, and $\partial E_a/\partial I_a$ is much less, and therefore the voltage amplification $\partial E_a/\partial E_g$ is less than in the ordinary case.

Several connections are given for two valve amplifiers, and some experiments over a range of frequencies (400 to 1,100) showing resonance effects at 600 to 800.

369. A HETERODYNING WAVEMETER. J. Scott-Taggart. (*Electrician*, 83, p. 243, September, 1919.)

A description is given of the usual type of C.W. wavemeter containing an oscillating valve, with telephones in the anode circuit. Measurements are made by adjusting the instrument until the beat frequency obtained by the interference of the wavemeter oscillations with the oscillations to be measured, becomes zero. The required wavelength is the midpoint of the silent or "dead" space.

370. HETERODYNE RECEPTION. H. Salinger. (*Physikalische Zeitschrift*, 20, pp. 488—490, November, 1919.)

This method is not suited to the determination of the component oscilla-

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tions in the received wave, since, owing to the curved characteristic of the detector, various combination tones arise so that audible beats are obtained even when the two composed oscillations are pure harmonics of very different frequencies if one is a multiple of the other. Thus if the received signal has $\lambda_1 = 8750$ metres, then audible notes are obtained when the superposed oscillation has the following wavelengths, $\lambda_2 = 1675—1750$; 2060—2190; 2750—3000; 3900—4600; 7500—10400 metres. In the experiments filters were used to ensure purity of the oscillations.

371. IMPROVEMENTS RELATING TO WIRELESS SIGNALLING SYSTEMS. General Electric Company U.S.A. (*British Patent* 134585, October 4th, 1918. Patent accepted, November 4th, 1919.)

In order to minimise the effect of static disturbances on the receiving instruments, amplitude pulsations of inaudible frequency are produced either by the generation in the transmitting aerial of oscillations of two frequencies, or by supplying the second frequency from a local source at the receiving station. The currents of inaudible frequency are accumulated in a resonant circuit at the receiving station, and are detected by heterodyning from a low frequency generator or otherwise. In the transmitting arrangement described, the output of a high frequency alternator is controlled by two magnetic modulators of the Alexanderson type through which alternating currents are sent of frequencies of the order of 5,000~. The windings of these modulators are so arranged that during one half cycle the reactance of one of them is a minimum and that of the other is a maximum. The aerial is doubly tuned to two frequencies namely, the main oscillation frequency ± the local oscillation frequency (which in this case is taken as 5,000).

The Fig. 13 indicates an arrangement of receiving apparatus with a

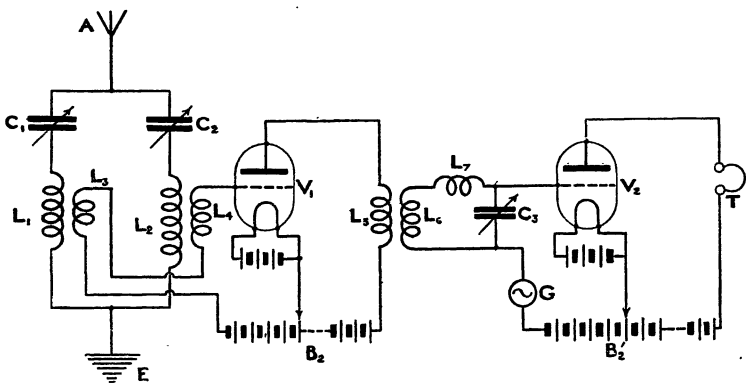

FIG. 13.

doubly tuned aerial suitable for picking up the wave emitted from a transmitter of the above type. The two branches of the aerial circuit C_1L_1 and

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C_2L_2 are tuned respectively to the two frequencies. The valve amplifier V_1 magnifies the pulsations of inaudible frequency and the circuit $L_6L_7C_3$ is tuned to this frequency. The oscillations are heterodyned by the local generator G of slightly different frequency to the difference between the two frequencies emitted by the transmitter and are then detected by the valve V_2 and the telephones T. Alternatively a highly damped or aperiodic aerial circuit may be used in place of the branched doubly-tuned aerial indicated in the figure. Fig. 14 indicates an arrangement of receiving apparatus adapted

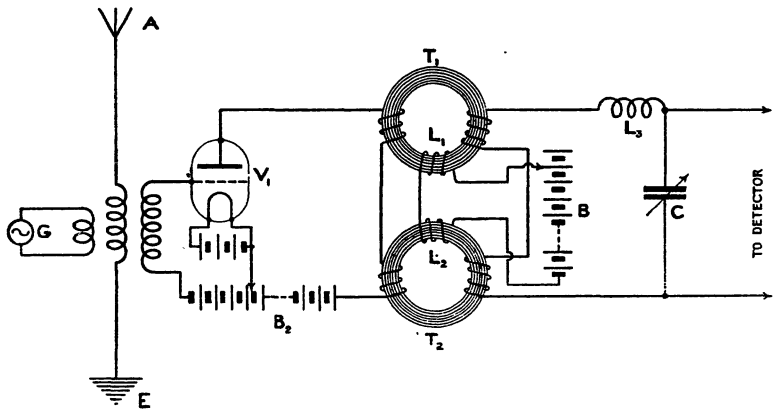

FIG. 14.

to receive waves of a single radio frequency only, the amplitude pulsations of inaudible frequency being produced by beats with a local high-frequency generator G. The circuit L_3C is partly screened from the effects of static disturbances by the inter-position of the two iron-cored transformers T_1T_2 which are provided with regulating windings L_1L_2 excited from a battery B. These transformers serve to limit the voltage that can be transmitted to the circuit L_3C as excessive shocks due to atmospherics produce saturation in the iron cores. Other slight modifications are also described in the original.

372. TRANSMITTERS. Compagnie Française pour l'Exploitation des Procédés Thomson-Houston. (*French Patent* 497446, March 22nd, 1919. Published December 5th, 1919.)

The invention relates to systems for generating oscillations. For further particulars, see British Patent No. 134585.*

373. WIRELESS SIGNALLING. Siemens and Halske, Akt.-Ges. (*British Patent* 135177, November 7th, 1919. Convention date June 18th, 1918. Patent not yet accepted but open to inspection.)

The arrangement described is shown diagrammatically in Fig. 15. The

* RADIO REVIEW Abstract No. 371.

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incoming oscillations from the aerial circuit AL_1E are heterodyned to a supersonic beat frequency by the local source of oscillations H which is

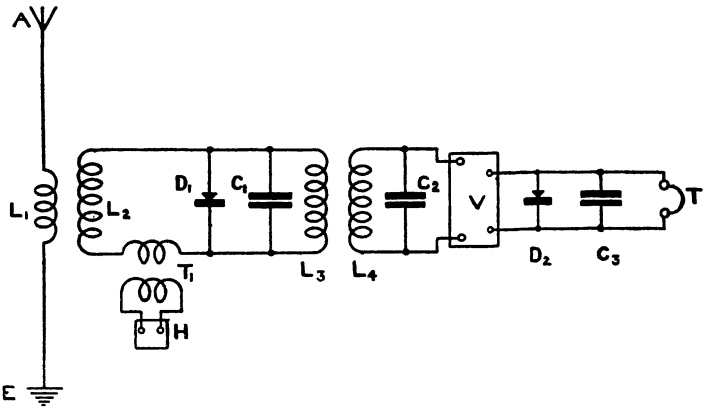

FIG. 15.

coupled to the secondary circuit L_2D_1 by the small transformer T_1. The supersonic beat currents are rectified by the detector D_1 and pass through the tuned circuits C_1L_3 and C_2L_4 to the amplifier V. Amplified supersonic beat currents are rectified by the detector D_2 and are thence passed to the receiving telephones T.

374. WIRELESS RECEIVING APPARATUS. E. F. W. Alexanderson. (*British Patent* 133965, October, 1918. Abridgment published December 17th, 1919.)

This receiver is particularly arranged for detecting signals from one station and at the same time cutting out signals from a second (interfering) station. The essential features are the use of aperiodic horizontal aerials each connected to a phase rotator consisting of two branches in parallel, through one of which the current lags and through the other it leads with respect to the impressed E.M.F. The

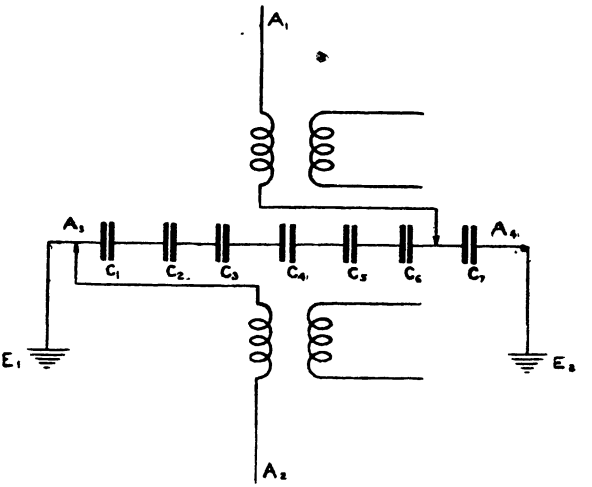

FIG. 16.

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circuit diagram is that of the "Barrage Receiver" dealt with in RADIO REVIEW Abstract No. 75 (Fig. 4).

An arrangement is also described for varying the effective direction of a pair of horizontal aerials A_1, A_2 (Fig. 16) by connecting them to different points on a distributed capacity circuit joining the earthed aerials A_3, A_4, mounted geographically at right angles to the main aerials A_1 A_2. Such a circuit is indicated at $E_1A_3C_1C_2$ . . . $C_6C_7A_4E_2$. The arrangement is stated to be useful for neutralising atmospherics coming from any particular direction.

375. RECEIVERS FOR WIRELESS TELEGRAPHY. C. S. Franklin. (*British Patent* 134246, June 28th, 1918. Patent accepted, October 28th, 1919.)

A wireless receiver specially adapted for short waves is arranged as indicated in Fig. 17 so that the variations in potential produced by the received wave cause the potential of the filaments relative to its windings to vary more than the potential of the other electrodes. The diagram shows the connec-

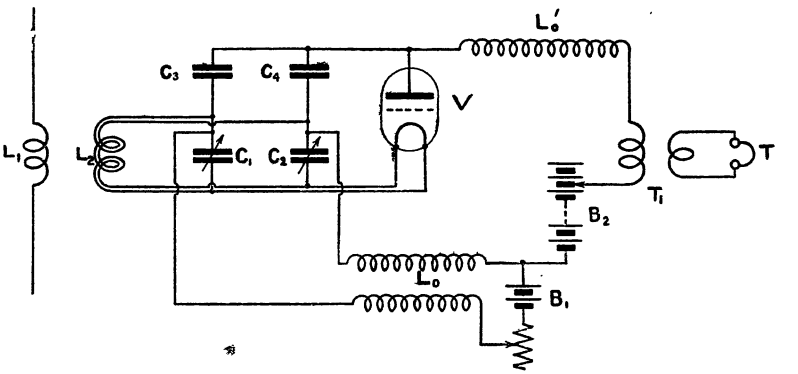

FIG. 17.

tions of a two-electrode valve receiver in which the two leads from the filament battery B_1 to the valve filament are wound together to form the secondary of the coupling jigger. The connections from the ends of these double windings to the battery B_1 are made through the choke coils L_0. The secondary tuning condenser is in two parts C_1C_2 across the two windings. By this means the capacity at the filament end of the secondary winding is reduced to a minimum.

376. AERIAL CONSTRUCTION. J. Bethenod. (*French Patent* 497313, April 20th, 1918. Published December 3rd, 1919.)

This specification describes a new system of aerials for the emission of electric waves of long wavelength produced either by a high-frequency alternator or by an arc, and it consists in the combination of two aerials

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at right angles and submitted to impulses which are out of phase with each other.

377. IMPROVEMENTS RELATING TO WIRELESS SIGNALLING SYSTEMS. J. H. Rogers and H. H. Lyon. (*British Patent* 133083, November, 1916. Patent accepted, October 9th, 1919.)

The radiating and receiving conductors of a wireless signalling system are placed on, or beneath, the surface of the earth, or water, and in electrical contact therewith. For directive or multiplex working it is proposed that several such conductors should be used arranged in different directions with the provision of suitable switches for using one or more of these aerials as requisite.

378. UNDERGROUND RADIO MADE POSSIBLE FOR AMATEURS. E. T. Jones. (*Radio Amateur News*, 1, pp. 274—275, December, 1919.)

The arrangement described aims at eliminating the long trenches required for the usual type of "ground aerials." The two horizontal aerial wires which are normally stretched out along or under the ground surface are in the arrangement described wound up into two coils of from 2 to 4 feet diameter each. The coils are sunk in water from 4 to 15 feet or buried in damp earth. One end of each coil is insulated and the other brought up to the ordinary valve receiving set. In the experiments described good signals were apparently received from a number of stations at a considerable distance and working on various wavelengths. The signal strength increased with the distance between the coils up to about 30 feet. About fourteen turns of cable were used on the 4-foot coils, and it is stated that practically no signals were received on them until they were lowered into the water or buried in the damp soil. When using the ordinary straight wire ground aerials, receiving on short wavelengths requires the use of a critical length of wire to obtain best results, but with the coils used in these experiments the length of wire did not materially affect the reception unless it was greater than about 500 feet on each coil.

379. THE WIRELESS EQUIPMENT OF EX-GERMAN SUBMARINES. E. Harper. (*Post Office Electrical Engineers' Journal*, 12, pp. 155—169, October, 1919.)

An illustrated description of the Telefunken apparatus installed in those vessels. In the standard sets a quenched spark transmitter with zincite-bornite crystal receiver was used. The discs of the quenched spark were an alloy of 80 per cent. silver and 20 per cent. copper.

In some sets two or three valve low-frequency amplifiers were added to the above to increase the range. A few of the submarines were provided with an additional box of apparatus containing three valves. These could be used for heterodyne reception or for short-range C.W. transmission. Some particulars of the windings, etc., are given in the paper together with characteristic curves of the valves and photographs of the apparatus.

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380. GREAT WIRELESS STATIONS: TOWYN. (*Wireless World*, 7, pp. 433—437, November, 1919.)
An illustrated description of the Towyn Trans-Atlantic Receiving Station.

381. THE NEW BRUNSWICK RADIO STATION. (*Radio Amateur News*, 1, p. 276, December, 1919.)
A short description with illustrations of some of the machines.

382. THE LARGE FRENCH WIRELESS STATIONS DURING THE WAR. (*La Nature*, 47, pp. 374—384, December, 1919.)
This article is divided into five sections describing in a general way the war-time work and developments of the wireless stations at the Eiffel Tower, Lyons, Nantes, Bordeaux, and in the French Colonies. The first arc sets installed at the Eiffel Tower yielded 40 kw. in the aerial. Later this was increased to 100 kw. An extensive scheme of listening stations was arranged around Paris for the interception of all messages sent from enemy or neutral stations. Throughout the war these stations intercepted some 50,000,000 words, while the Eiffel Tower station itself sent about 1,500,000. It was even found possible to decipher messages from German stations when these were sent with a Hughes transmitter, by running an appropriate receiver in synchronism. The Lyons station was entirely erected during the war, and commenced work with a 150-kw. spark-set putting 50 kw. into the aerial. Later an arc was installed giving 70 kw. in the aerial, which was subsequently increased to 100 kw. by improvements in the arrangements. The eight 400 feet towers first installed were increased in height (two to 675 feet and six to 600 feet) to ensure reliable communication with America. This station has been heard in Central Africa, Shanghai, the Philippines, and New Zealand. Arcs giving 200 kw. are also to be installed. A 200-kw. 20,000 ~ alternator was installed in July, 1919, and gives better signals in America than the 200-kw. arcs. The Nantes station erected by the French naval authorities has 30- and 150-kw. spark sets and three arc sets similar to that at the Eiffel Tower. The Bordeaux station is to contain a 300-kw. arc, a 500-kw. arc, and two 500-kw. alternators, to work on 20,000 metres wavelength. The aerial is 820 feet high and 5,000 feet long. A station is to be erected in Indo-China having similar equipment.

383. THE TECHNICAL PROGRESS IN LARGE WIRELESS STATIONS. (*La Nature*, 47, pp. 387—389, December, 1919.)
A brief description is given of the mode of operation of the Goldschmidt alternator, and of the various means of producing undamped waves. The chief lines of progress have been the substitution of undamped for damped wave transmission, the use of automatic transmitters, the use of amplifiers enabling reception to be effected with frame aerials, improvements in anti-atmospheric devices, automatic reception, and the use of frame aerials for duplex working. A brief account is also given of Levy's anti-atmospheric

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arrangement using a double heterodyne—the first to 10,000 ~ and the second to an audible note.*

384. NAUEN AND COUNT ARCO. (*Elektrotechnische Zeitschrift*, 40, p. 653, December, 1919.)

The high-power station at Nauen is being rebuilt and fitted with new equipment. The history of Nauen is described in a special number of the *Telefunken Zeitung* issued in honour of Count Arco's fiftieth birthday. The articles deal with the various branches of the wireless plant, including duplex working.

385. SOME FOREIGN APPARATUS. F. M. Gill. (*Radio Amateur News*, 1, p. 282, December, 1919.)

Circuit diagrams are given of the various French amplifier, wireless telegraph and telephone, and aeroplane sets also of a French spark transmitter for trench use and the French wavemeters which were supplied to the U.S. Signal Corps.

386. TRANSMITTERS. H. Thuret and L. Louvel. (*French Patent* 497299, March 19th, 1919. Published December 2nd, 1919.)

The invention described in this specification consists of an automatic keyboard sender which may be used in sending Morse or other signals in wireless telegraphy. For each key a rotating shaft, whose speed may be regulated, is disposed transversely to and above the keys. A disc of insulating material is loosely mounted on the shaft and carries conducting segments. Two conducting members arranged to bear against the disc are connected to the transmitting circuit and means are provided to connect each disc automatically to the shaft by depressing its controlling key, whereby the said disc rotates and signals are produced.

387. NEW RADIO DYNAMIC CONTROLLING SYSTEM. W. R. Coventry. (*Radio Amateur News*, 1, p. 293, December, 1919.)

Two synchronously rotating contact drums are used and the contacts are controlled by signals sent at the appropriate instant.

388. OSCILLATORY MERCURY "MAKE AND BREAK" APPARATUS FOR WIRELESS TELEGRAPHY. M. Compare. (*British Patent* 134297, October 29th, 1918. Patent accepted, October 29th, 1919.)

The relay described is for use in wireless control systems and is arranged to be responsive only to impulses of a particular frequency. It consists of a vertical column of mercury or other liquid partly filling a tube having a sealed upper end with a magnetic float on the surface of the mercury. This float is

* See also RADIO REVIEW Abstracts Nos. 190 and 191.

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under the influence of a solenoid which encloses the tube and through which the received currents are passed. The lower end of the tube dips into a containing vessel in which two contacts are mounted above the surface of the mercury. When impulses of the correct frequency are passed through the solenoid winding an oscillation is set up in the mercury column which increases in amplitude until the contacts are closed.

389. RADIO PROBLEMS IN AVIATION. E. R. Doyle. (*Electrical Experimenter*, 7, p. 543, October, 1919.)

The problems considered are: (1) Directional control of transmitted signals; (2) wavelength adjustment of incoming and outgoing signals; and (3) transmitting ranges and sensitivity of receiving apparatus.

390. ON THE FORM OF THE TRAILING AERIAL. H. C. Plummer. (*Philosophical Magazine*, 38, pp. 732—736, December, 1919.)

A mathematical treatment of the form taken up by a wire aerial hung from an aeroplane in flight.

391. ELECTRIC SWITCHES SPECIALLY SUITABLE FOR USE IN WIRELESS SIGNALLING. M. D. Scott and P. P. Eckersley. (*British Patent* 134590, October 26th, 1919. Patent accepted, November 13th, 1919.)

This relates to electromagnetic switches specially suitable for use on aircraft for changing over from wireless reception to transmission and *vice versa*. The switch is particularly adapted for use with thermionic valve transmitters, and is arranged to dim the filaments of the transmitting valves when the receiver is connected to the aerial. The generation of oscillations by the transmitting valves is thus stopped during reception. By this means the complete change over from transmission to reception can be effected with a small local switch or push button.

392. A METHOD OF DEMONSTRATING THE EDISON EFFECT. (*Annales des Postes, Télégraphes et Téléphones*, 8, p. 551, September, 1919.)

A telephone joined between the earth and a band of tinfoil wrapped round an ordinary electric lamp indicates the passage of a current due to the Edison effect. This current passes *through the warm* glass.

393. WIRELESS RAILWAY SIGNALS. (*Electrical Review*, 85, p. 721, December, 1919.)

Brief mention of an apparatus operated by radio to give a warning in the engine cab when a train passes a danger signal.

394. WIRELESS STATIONS AS COMPETITORS WITH LINE TELEGRAPHY AND TELEPHONY. E. Nesper. (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 69—72, January, 1920.)

An article drawing attention to the advantages of wireless telegraphy and

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the possibility of relieving the present congestion and cheapening communication.

395. WIRELESS PRESS SERVICE. Communicated by the Gesellschaft für Drahtlosen Telegraphie (*Jahrbuch der Drahtlosen Telegraphie*, 15, pp. 72—76, January, 1920.)

A plea to the German authorities for the establishment of a system of distribution of news from wireless stations.

2. Books.

LA THÉORIE ET LA PRATIQUE DES RADIOCOMMUNICATIONS. Vol. I. INTRODUCTION À L'ÉTUDE DES RADIOCOMMUNICATIONS. By Léon Bouthillon. (*Paris: Librairie Delagrave* Pp. ix. + 193. Price 20 fr. paper covers; cloth, 25 fr.)

This volume is the first of a series of eight dealing with the whole subject of radiotelegraphy, both in its theoretical and its practical aspects. The author states in his preface that he has come to the conclusion that it is more satisfactory to publish such a work in a series of volumes, each dealing with one particular branch of the subject, than to attempt to include everything in a single volume, unwieldy in size and prohibitive in price.

He also expresses a doubt whether such a book is needed when there are already so many in existence; but this volume seems to show that there should be a place for his work which is not quite filled by any author. During the war, owing to the necessities of the case, the practical side of radiotelegraphy made enormous advances; but these advances were hardly paralleled on the theoretical side, and the urgent need of the moment is a consideration of the more abstract side of the subject, in order to obtain the full value of the practical results already obtained.

For the ordinary operator or erecting engineer, the mathematical side of the subject is not of such great importance, and for men of this type there are many small handbooks in existence suitable to their particular needs; but it is absolutely indispensable for any worker who wishes to deal with fundamentals. In many books on radiotelegraphy there is a tendency to sacrifice either the theoretical or the practical side, generally the theoretical, as this is the side which appeals to fewer readers. Hence anybody who wishes to study first principles is usually obliged to refer to original papers dealing with the mathematics of the subject, or to a condensed edition of them.

In such editions, not only in books on this subject but in many others, portions of a mathematical discussion are frequently left out, and this renders it very difficult for the argument to be followed. "Hence it follows" may be made to cover several pages of close mathematical reasoning, and one is at times driven to the conclusion that such cuts have been made with greater vigour than discrimination. Even ordinary papers require editing in view of the special requirements of their subject which may not have

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appeared of immediate importance to the author at the time he wrote his work. For instance, Maxwell knew nothing of, and had no direct interest in radio communications. He was entirely concerned in the development of his theory of electrical actions in material space. Consequently, when his work is applied to radio communications, the relative order of importance of his results may differ considerably from that in which he placed them himself. Such editing has been particularly well carried out in this work; the mathematical reasoning, without being prolix, is presented in a form which makes the argument very easy to follow, and gives the definite impression that the author is fully at home with the mathematics of his subject.

He himself would probably be the last to claim originality for most of the work in this volume. He has taken the results of the classical researches on the subject, and has arranged and prepared them to form a continuous whole leading directly to the results he has in view. This particular volume, of course, demands of its readers considerable familiarity with the mechanical processes involved in the handling of differential equations, and immediate recognition of the standard forms of equations dealing with wave-motion, and the physical interpretation of the symbols that occur. This amount of mathematical skill is unfortunately very infrequent among radio engineers in this country and the subject suffers considerably therefrom. Experimental work of the " hit and miss " type is far too common, and the idea of basing it on a mathematical foundation is looked on as impracticable by many experimenters.

The first chapter deals almost entirely with Maxwell's equations and their derivatives, special attention being given to the case in which the electromagnetic field is symmetrical about one axis, *i.e.*, a field of revolution; and to the case in which the frequencies involved are of the order used in radio work. In particular, a full discussion is given of vector potential. This is probably one of the most difficult points in the mathematics of the subject. From the purely mathematical standpoint, the vector potential appears as an abstract arbitrary function, whose chief purpose is to effect a symbolic reduction of the equations to a more workable form. It is thus primarily defined by a mathematical substitution in the original equations, but the conditions it has to satisfy for this purpose do not define it uniquely, and so there is one other independent condition available. By postulating this condition differently, Maxwell, Hertz and Lorenz have each arrived at a different function to suit the particular case they had under consideration. Poynting's theorem and the problem of the diffusion of electromagnetic effects into a conductor are also briefly discussed.

The second chapter occupies most of the book. The first part of it deals with the form taken by Maxwell's equations for a perfect dielectric, and is, therefore, of primary importance in radiotelegraphy. Throughout the chapter only two cases are considered in detail, first the field of revolution, in order to deal with the radiation from a source on the axis, and the effects in its immediate neighbourhood; and secondly the case of a plane wave front, which is the condition that holds for reception at a considerable

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distance from the source. The method of Hertz for obtaining the graphs of the lines of force radiating from an undamped oscillator at various phase times is given in detail with a great many diagrams, and there are also full references to the works of Professor Karl Pearson and Miss Lee, and also to that of A. E. H. Love dealing with damped oscillations.

In the latter part of the chapter the problems of transmission and reception from both closed and open aerials are discussed. The special object in the case of transmission is to obtain an expression for the power radiated under given conditions, and the efficiency of such radiation; and in the case of reception to determine the power absorbed from the dielectric by the receiving system and its efficiency. The results are given in two tables, which give these efficiencies both for the general case and also for cases in which special relations exist between the various constants of the aerial. The results for reception are based on the assumption that the atmosphere is a perfect dielectric; and a table is given showing for different wavelengths the power which must be radiated to give a power of four microwatts in the receiver. Of course, on this assumption, no account is taken of the actual conditions which arise in practice, such as reflection from an ionised upper layer of the atmosphere or losses due to the resistance of the surface of the earth. Hence the results are very different from actual results which would be obtained in practice. For example, the table shows that with a radiated power of 16 kw. at a wavelength of 2,000 metres, the power mentioned above, 4×10^{-6} watts can be received at a distance of 15,040 km. Experience, especially with continuous waves, tends to show that these distances are excessive and also that it is probable that the power received is not proportional to the inverse square of the distance, as is assumed in these calculations, so that care should be used in applying them to a practical case.

The third chapter discusses the mathematics of radiation over a plane perfectly-conducting surface; the ideal case of transmission over the surface of the earth. A few special cases of simple aerial forms are discussed; but as the author himself says this is approaching the practical side of the question, and so a full discussion of it is left to a later volume. This is the only weak point of the system by which a different volume is allotted to each branch of the subject, namely, that it is difficult to draw a sharp line of distinction between the theoretical and the practical side of the problem. This disadvantage is, however, far outweighed by the advantages of the system.

A comparative table is given of the reception of the same signal by open aerials and closed coils of various dimensions, showing the range and the efficiency obtained in each case. These are, of course, open to the same objections as the table referred to above, namely that these figures would probably not be substantiated in actual working, although the relative values may be correct.

In the fourth chapter the results of the rest of the volume are summarised and at the end of each chapter a bibliography is given of the references to the original papers from which the results have been taken.

J. HOLLINGWORTH.

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MESURES PRATIQUES EN RADIOACTIVITÉ. W. Makower and H. Geiger. Translated from the English by E. Philippi. (Paris: *Gauthier-Villars et Cie.* 1919. Pp. vii. + 181. Price 12 fr.)

We welcome the translation of Makower and Geiger's "Practical Measurements in Radioactivity" as an earnest of the resumption of Anglo-French publishing relations, rudely arrested by the war. Doubtless owing to the difficulties of the times, the translation bears no marks of any attempt to incorporate the results of work published subsequent to 1912—the date the book first appeared in this country.

Radioactivity, as a subject, has now been added to the syllabus of instruction of most of the physical laboratories in this country—certainly in the case of students contemplating a medical career. The authors of the present volume can fairly claim a large share of the credit for bringing this about. They clearly demonstrate that a laboratory course in radioactivity requires only simple and inexpensive apparatus. With the assistance of many excellent diagrams they set out the main points which are likely to worry the novice or for the matter of that the more knowledgeable student. Here and there the treatment is perhaps meagre, and now and again unexpectedly complete, probably owing to the fact that the authors have not been able to fall back on the crop of graded text-books common to other branches of physics.

The French edition follows precisely the English one in its sequence of chapters dealing in logical order with electrometers and electroscopes (string-electrometers should receive better treatment), the *alpha*, *beta* and *gamma* rays of radium, methods of measuring ionisation as the basis of standard measurements, etc.

We notice a small slip on p. 101 where in equation 39, P should read Q. The book concludes with some useful tables of constants and an index which leaves a good deal of room for improvement. The translator appears to have done his work well.

We know of no other work which seeks to impart the technique of radioactivity to the student. The book may fairly be recommended to the reader who wishes to know some of the details of the methods employed in a subject which has profoundly affected the fundamentals of physics.

G. W. C. KAYE.

Books Received.

LEÇONS DE PHYSIQUE GÉNÉRALE. By J. Chappuis and A. Berget. Vol. II. ELECTRICITY AND MAGNETISM. Revised by J. Chappuis and M. Lamotte. (Paris: *Gauthier Villars et Cie.* Third Edition. 1920. Pp. 623. Price 45 fr.)

MANUAL OF RADIOTELEGRAPHY. By Captain S. Robison, U.S.N. Revised by Captain D. W. Todd and Commander S. C. Hooper. (Annapolis, U.S.A.: *The United States Naval Institute.* London: *S. Rentell & Co.* Fifth Edition. 1919. Pp. 307. Price 10s. net.)

TELEPHONIC TRANSMISSION, Theoretical and Applied. By J. G. Hill. (London: *Longmans, Green & Co.* 1920. Pp. xvi + 398. Price 21s. net.)

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ANNUAIRE POUR L'AN 1920. By Le Bureau des Longitudes. (Paris: *Gauthier Villars et Cie.* 1920. Pp. viii + 708 + A. 27 + B. 64 + C. 70. Price 4 fr. 50 net.)

This Annual contains in addition to extensive astronomical information, physical and chemical particulars arranged mostly in tabular form for reference purposes, as well as a number of electrical constants, etc. An appendix contains an article by C. Lallemand setting out full particulars of the new metric system units legalised in France.

LA TELEFONIA SENZA FILO. By Umberto Bianchi. (Milan: *Ulrico Hoepli.* 1920. Pp. viii + 296. Price L. 10.)

REPORT OF THE CHIEF SIGNAL OFFICER (General G. O. Squier) TO THE SECRETARY OF WAR, U.S.A., 1919. (Washington: *Government Printing Office.* 1919. Pp. 547.)

RADIO ENGINEERING PRINCIPLES. By H. Lauer, B.S., and H. L. Brown, B.E.E. (New York: *McGraw-Hill Book Co., Inc.* London: *Hill Publishing Co., Ltd.* 1920. Pp. xv + 300. Price 21*s.* net.)

THE "PRACTICAL ENGINEER" ELECTRICAL POCKET BOOK AND DIARY, 1920. (London: *The Technical Publishing Co., Ltd.* Pp. clxiv + 592 + 56 (Diary). Price 1*s.* 6*d.* net; best cloth binding, 2*s.* net.)

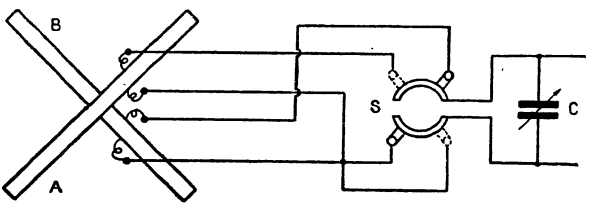
Correspondence.

WIRELESS DIRECTION FINDING.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In No. 5 and 6 of the RADIO REVIEW Captain Robinson describes a maximum method of direction finding with crossed coils.

Methods of direction finding using crossed coils were experimented with and developed at the National Physical Laboratory in the winter of 1914, and it may be of interest to describe two of these methods. In one method two direction finder coils A and B are wound at right angles to each other



and are capable of being rotated together about a vertical axis. The coils are similar and are used independently, each in turn being placed in circuit with the tuning condenser C by means of the switch S. If the coils A and B are exactly at 45° to the direction of the incoming signals the intensities of the received signals will be equal.

If the coil A be at an angle $45° + d\theta$ to the incoming signals then the ratio of the E.M.F.'s in the two coils is equal to $1 - 2 \sin d\theta$, and the ratio of the difference of E.M.F. to the mean E.M.F. is $2 \sin d\theta$. This ratio is identical with that obtained with Captain Robinson's system if he uses two similar coils.

It may be urged that this 45° system is nevertheless at a disadvantage, for apparently the maximum intensity of the received signals is less. In

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practice, however, this is not the case. In Captain Robinson's method the two coils are in series; in the 45° method each coil is used independently, and for the same values of the capacity and diameter of coils the inductances must be the same. That is, there will be approximately $\sqrt{2}$ times as many turns on each of the coils A and B as on a Robinson coil, with a corresponding increase in the E.M.F. However, in the one case a coil is at 45° to the direction of the incoming signals and in the other case at 0° which results in the E.M.F.'s for similar coils being in the proportion $1 : \sqrt{2}$. Allowing for the difference of turns the final result is therefore that the E.M.F.'s are equal. The effective resistance of the circuit of an A or B coil will however be less than for the Robinson coils which is a slight advantage.

Obviously it is not possible with this method as it is with Captain Robinson's to vary the diameter of one of the coils and so obtain a greater ratio of the difference of E.M.F. to the mean E.M.F. In practice, however, it must be possible to rotate the coil systems and hence whatever the size may be of Captain Robinson's auxiliary coil it is possible for each of the coils A and B to be of equal diameter. It follows therefore that with the auxiliary coil system it is not possible to obtain a greater *difference* of E.M.F. for a small variation $d\theta$ from the desired position but it is possible to add this difference to a smaller E.M.F. than in the method of 45°. Two questions immediately arise:—(1) What is the smallest change of intensity which the ear can detect? and (2) Is the ear *more* or *less* sensitive to a change of intensity when the change is superposed on another note of the same frequency? In general I believe the ear is more sensitive when there is no added note. Assuming this to be so, the most sensitive coil system is that of a single coil and the writer has obtained some remarkably consistent results when the signals were of sufficient intensity to necessitate an angular movement of a few degrees only. One disadvantage lies in the necessity to rotate the coil to compare the two notes, and it was with a view to overcoming this difficulty that the second method of crossed coils, now to be described, was devised. In practice the system is not equivalent to that of a single coil but in sensitiveness it appears to be equivalent to the Robinson method with a main and an auxiliary coil. If arrangements are made to alter the angle between the coils it appears to be equivalent to the Robinson system plus the advantage which would result if the main coil of the latter could be arranged to have its "area-turns" varied without altering the inductance.

The two coils are equal and similar as before but instead of being crossed at 90° the angle between the coils is smaller, for example 20°. Observations can be made with the system when its mean plane (each coil being 10° from the plane) is (*a*) at right angles to the direction of the incoming signals and (*b*) in the direction of the signals. A switch similar to that employed in the previous method may be used to compare the intensities.

In the case where the angle is 20°, and the displacement from the correct minimum position is $d\theta$ the ratio of the E.M.F.'s in the two coils is equal to $1 - 11{\cdot}4 \sin d\theta$, and the ratio of the difference of E.M.F. to the mean E.M.F. is $2 \tan 80° . \sin d\theta = 11{\cdot}4 \sin d\theta$. The latter ratio depends on the angle between the coils and may be varied to suit special cases.

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With such a crossed coils system the intensity of the incoming waves may not be sufficiently great for the latter to be detectable when the plane of a coil is 80° from the maximum position and in such a case the method would fail. It may be pointed out, however, that for similar signals and for a similar ratio of difference of E.M.F. to mean E.M.F. the Robinson system of small main coil and auxiliary coil would also fail. To obtain the ratio of $11{\cdot}4 \sin d\theta$ the ratio of the area turns of the auxiliary coil to those of the main coil would have to be 5·7 (this is $b/a = k$ in Captain Robinson's notation) and since the area turns of each of the 80° coils can be equal to the area turns of the auxiliary coil it follows that the E.M.F. produced in such a coil 80° from the maximum position is $5{\cdot}7 \cos 80°$ (= 1) times that of Captain Robinson's main coil in the maximum position. That is, the E.M.F.'s are equal and if one system fails to pick up signals the other will also. The obvious remedy is to use the auxiliary coil as the main coil and work in the maximum position. This of course sacrifices sensitiveness. Similarly with such a system as I have termed an 80° system; when the mean plane is near the "maximum" position the displacement being $d\theta$, the ratio of the E.M.F.'s in the two coils will be equal to $1 - 0{\cdot}35 \sin d\theta$ and the ratio of the difference of E.M.F. to the mean E.M.F. is $2 \tan 10° \sin d\theta = 0{\cdot}35 \sin d\theta$.

It will I hope be clear that in designing any D.F. coil system the all-important question is that of the intensity of the received signals. The 80° system as I have called it was experimented with but little, but I did observe some slight interaction between the coils. This interaction did not influence the accuracy of the results but there was evidence of a small reduction in the intensity. For general work I am inclined to prefer two equal coils crossed at right angles used either independently or as a Robinson maximum system. In aircraft work it is essential to have considerable intensity, and the minimum method using a single coil, is therefore disadvantageous. I would like to point out that the disadvantages of a single coil were brought to my notice by an officer of the R.N.A.S. (there was no R.A.F. then) in 1916. At this time what I believe to be the first D.F. coil ever taken in the air in this country was being made at the National Physical Laboratory and I proceeded at once to devise "intensity and difference" methods instead of minimum intensity methods. These methods I am now at liberty to describe and I hope they will be of some interest to your readers.

F. E. SMITH.

The National Physical Laboratory,
Teddington, Middlesex,
March 11th, 1920.

TRIODE NOMENCLATURE AND SYMBOLS.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—With reference to Mr. L. B. Turner's letter in your last number, I am very glad to see that the question of symbols and nomenclature for use with thermionic valves and the associated circuits is being discussed.

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The k_1, k_2, k_3, and k_4 of my paper were chosen provisionally in 1915, after careful consideration of other possibilities. The letter g being in very general use for conductance was naturally the first suggestion. But there were certain objections to this choice. In the first place the slopes of the characteristics are not exactly conductances. Again, there are in the associated circuits true conductances, for which the g is required in its usual sense.

With regard to the use of k, this was to some extent justified by the fact that the slopes of the characteristics are constants in most problems. The values are only altered by alterations of the batteries or controlling resistances. They are not affected by the functioning of the valve itself.

For each of these reasons therefore the choice of the letter k seemed to be justified.

The question of distinguishing subscript numbers or letters then arose. If letters were to be used it would have meant that two subscript letters would have been required if they were to have indicated the particular slopes referred to. Consequently the numbers 1, 2, 3, and 4 were chosen and applied to the slopes in the order of their respective importance.

This notation has proved quite satisfactory in practice.

The letter k without subscript could be used for the slope of the "lumped characteristic," if this is required.

For the voltage ratio of the tube, *i.e.*, the ratio k_1/k_2 in my notation, the letter m was chosen at the same time as the k_1, etc. There is some risk of confusion here with m or M for mutual inductance and an alternative is desirable. Dr. Eccles' g is not good, as confusion with conductance is likely. Mr. Turner's ν is very inconvenient to write and a change from m to μ might meet the case as confusion with permeability is scarcely possible.

With regard to Mr. Turner's proposals for names for the slopes, these seem to be quite sound and might well be generally adopted.

Dr. Eccles has recently introduced the term "lumped characteristic," used above. Cannot this name be improved upon? Why not simply "*the* characteristic" or the "total characteristic." Or again, would it be a misplaced compliment to call it the "Langmuir characteristic"?

C. L. FORTESCUE.

Royal Naval College,
Greenwich.
March 17th, 1920.

"TEXT-BOOK ON WIRELESS TELEGRAPHY."

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—A very fair review of my "Text-Book on Wireless Telegraphy," Vol. II., by Dr. Whiddington appeared in your February issue, and I have never before replied to criticism. Dr. Whiddington, however, takes me to

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task for giving so much credit to the French military service and so little to the work carried on under the auspices of the British services; perhaps you will therefore afford me a little space to explain my attitude.

I was intimately connected with the British Army wireless service for four and a half years and my experience was that our home establishments produced very little of an original nature. For example, right up to the end of the war, the French valve was our favourite at the front, and for all round adaptability nothing better than it was produced by our home department. Apart from the excellent range of valves introduced by the Marconi Co. we must admit that the French service deserves most of the credit for valve work, and it may be noted that even the Germans copied the French arrangement of hard valve in 1918. The valves brought over by the American army service were excellent in robustness of design and in characteristic.

In oscillation amplifiers we in France were acquainted with no design except those of the French service and of the Marconi Co.; if the British establishments discovered any improvements in such apparatus they certainly did not produce anything which could be of service in the field.

In L.F. amplifiers I think the patent records show that most of the honours should go to Latour and the French wireless service. We were using French amplifiers in February, 1916, and for almost two years the home establishment produced amplifiers which were not so flexible as the French ones, and of which the design was more applicable for dressing jewellers' windows than for use in the trenches. It was not until 1918 when the influence of German portable designs had at last penetrated that we obtained amplifiers from home of really serviceable construction.

Of C.W. Sets the less said the better; we in France started clamouring for serviceable Sets in 1916 but it was 1918 before we got a field pattern in which there was nothing original, and in which there was much faulty design.

The only evolutions of real importance and utility from our home establishment were the excellent C.W. Set designed by Mons. Matthieu, a Belgian, and the Loop Set of Captain L. B. Turner; had the war been further prolonged I believe also that Captain Turner's Wireless Telephone Trench Set would have been most useful.

I could not describe Mons. Matthieu's C.W. Set nor Captain Turner's Loop Set in my text-book because they are standard sets in the Army at present.

Dr. Whiddington says that "no one relying entirely on the text-book for information would for a moment suspect that any research or design had been carried out by the British Government along lines *parallel* to the French." If that is so I have been happily successful in my intention, for the difficulty of getting any serviceable design out of our home establishments was heart-breaking to every responsible wireless officer in the field. Far from being on parallel lines the productions of our home establishments were very much behind those of the French service, both in originality and in date.

As regards the Navy my information was that Dr. de Forest's circuits were largely employed; it was impossible to publish details of the Air Service

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apparatus, and in any case I have not dealt with air radio-practice in the text-book.

I was not aware that the Fullerphone had revolutionised earth signalling; the Fullerphone was employed in the field as an alternative method of line signalling. Dr. Whiddington thinks that in connection with L.F. amplifiers my use of the terms "amplifier" and "relay" may lead to some confusion; I can only say that I have taught some hundreds of operators and found it necessary to call on their previous knowledge of "relay" action in order to get them to really understand the simple theory of amplification.

RUPERT STANLEY.

Municipal Technical Institute,
Belfast.
March 15th, 1920.

The above letter has been submitted to Professor Whiddington, who has replied as follows:—

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In a letter to the RADIO REVIEW criticising my review of his book Mr. Stanley conveys an impression which I feel bound to correct.

Far from taking him "to task for giving so much credit to the French military service," I actually commended him most warmly for so doing. I also took the opportunity of recording my own deep appreciation of the great work done by the excellent scientific staff of the French military service.

What I did call attention to was the fact that Mr. Stanley had omitted *all* reference to British official design—an omission which I stated detracted from the value of his book.

It is interesting in this connection to learn from Mr. Stanley's letter that (leaving out of account the Navy and Air Force) there were in his opinion two sets designed in the Army establishment which were definitely useful and a third which might have been, if the war had lasted!

R. WHIDDINGTON.

The University, Leeds,
March 29th, 1920.

(We regret that owing to pressure on our space some correspondence has been unavoidably held over to the next issue.—ED.)

ERRATUM.

Page 318, *footnote*. The expression for a should read: $a \equiv \frac{\partial I}{\partial \overline{V}}$.

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THE

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THE
RADIO REVIEW

VOL. I JUNE, 1920 NO. 9

Refraction of Electric Waves.*

By T. L. ECKERSLEY, B.Sc.

It is well known to wireless engineers that it is more difficult to transmit wireless waves over land than over sea. Professor Zenneck and Professor Sommerfeld have explained fairly adequately how the absorption is produced and have shown theoretically how the conductivity and specific inductive capacity of the ground modify the values of the absorption coefficient. But it is not so generally known that the nature of the ground over which the waves travel determines the velocity of the waves.

The reduction in velocity is not a large quantity, but it is sufficient to have a marked influence in determining the direction of a ray which passes, for instance, over the boundary between sea and land.†

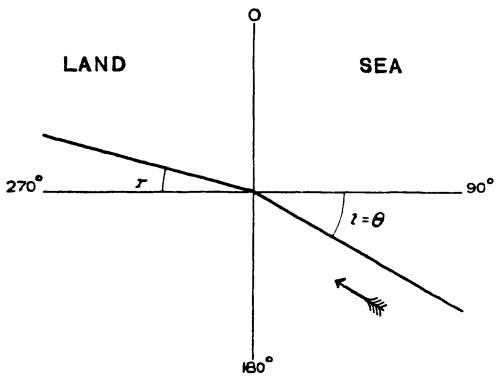

FIG. 1.

THEORY.

Suppose a wave travels from sea to shore in the direction of the arrow in Fig. 1, then at a few wavelengths inland, where the wave front has had time to settle down, the velocity of the waves will be the same in all directions (as the land is assumed to be more or less

* Paper received February 21st, 1920.

† [R. A. Fessenden, in describing in *The Electrician* of December 19th, 1919 (see RADIO REVIEW Abstract No. 431) the various causes of the discrepancies which were found in directional tests carried out in the United States during 1901—1906, says that " over water and parallel to a coast line, such as that between Cape Henry and Cape Hatteras, the error in direction was found to be due to the great difference between the resistance of the water and that of the sandy beach, causing the electromagnetic waves to bend in."—THE EDITOR, R.R.]

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isotropic), and it is possible to apply Huygen's principle, and therefore to infer that if V_1 is the velocity of the wave over land and V_2 the velocity of the wave over sea—

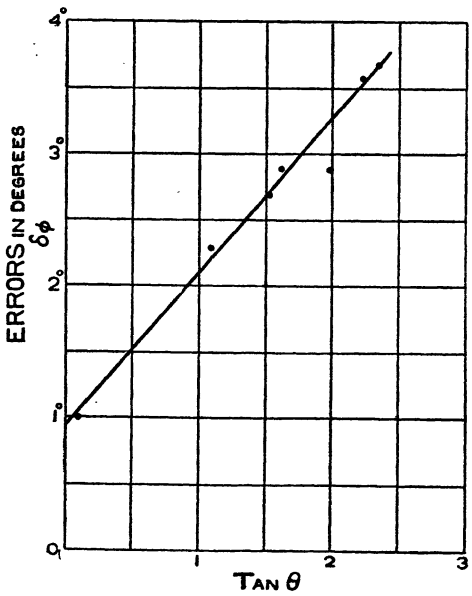
$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2} = \mu$$

where i is the angle of incidence, *i.e.*, the angle that the ray makes with the normal to the coast line, and r is the angle of refraction.

If the ratio V_1/V_2 is nearly unity, that is i is nearly equal to r then if $\delta\phi$ is the error in bearing and $\theta + 90°$ is the true bearing, it is easy to show that—

$$\delta\phi = \frac{\mu^2 - 1}{2\mu} \tan\theta$$

The curve (Fig. 2) shows diagrammatically some results obtained from a direction-finding station in Cyprus. The station was situated within a mile



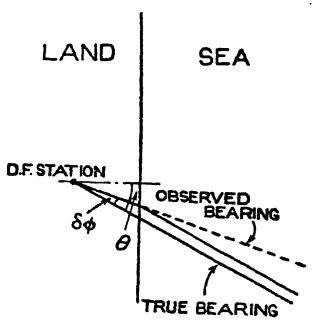


FIG. 2.

of the coast which ran nearly due north and south in the neighbourhood. The ordinates represent the errors in bearing of certain known stations plotted against the value of tan θ where θ is the true bearing — 90°.*

It will be seen that except for one observation the points lie very closely along a straight line. The error for $\theta = 0$, which is nearly 1°, agrees with the station error (determined fairly accurately with a theodolite).

* The bearings are reckoned in a clockwise direction from due north.

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The observations, it will be seen, confirm in a remarkable manner the theory, the agreement in all cases except one being within one-tenth of a degree. The points actually plotted were obtained from the mean day bearings taken over a period of five months (March to July, 1918), the number of bearings per month being, on an average, about twenty to fifty.

The true bearings were calculated from the known latitudes and longitudes of the transmitting and receiving stations.

The wavelength of the stations varied between 800 and 1,100 metres, and strictly speaking the results should only be compared for the same wavelength, for it will be shown later that the amount of refraction varies with the wavelength being almost negligible with wavelengths over 2,000 metres.

The ratio of the velocity of the wave over sea to that over land calculated from the slope of the straight line just given is 1·020, thus the velocity over sea in this case is only 2 per cent. greater than the velocity over land.

We can get an expression for the ratio of these velocities in terms of the constants of the soil and sea water respectively from Zenneck's analysis of the transmission of waves over land.

The expression for the ratio of the velocities μ can be shown to be

$$\frac{1}{\mu} = \left\{\frac{\sqrt{\sigma_1^2 + p^2 k_1^2}}{\sqrt{\sigma_1^2 + p^2 (k + k_1)^2}}\right\}^{\frac{1}{2}} \cos \frac{(\phi_1 - \phi_2)}{2}$$

where $p = 2\pi \times$ frequency, $\tan \phi_1 = \dfrac{pk_1}{\sigma_1}$, $\tan \phi_2 = p\dfrac{k_1 + k}{\sigma_1}$

$4\pi k_1$ = specific inductive capacity of ground.

$4\pi k$ = specific inductive capacity of air.

σ_1 = conductivity of ground (electrostatic units).

If p is small enough, *i.e.*, if the wavelength is so long that $p^2(k + k_1)^2$ is small compared with σ, then

$$\frac{1}{\mu} = \left\{\frac{\sqrt{\sigma_1^2}}{\sqrt{\sigma_1^2}}\right\}^{\frac{1}{2}} \cos\left(\frac{\phi_1 - \phi_2}{2}\right) = \cos\left(\frac{\phi_1 - \phi_2}{2}\right)$$

but in this case ϕ_1 and ϕ_2 are both very small and hence $\dfrac{1}{\mu} = 1$ and there is no refraction.

As an illustration we may consider the following cases:—

(1) Take $\lambda = 3{,}000$, $4\pi k_1 = 1$, $4\pi k_2 = 2$

$\sigma_1 = 9 \times 10^5$ (a reasonable value for dry sand).

Then $\dfrac{pk_1}{\sigma_1} = 0{\cdot}11$, $\dfrac{p(k + k_1)}{\sigma_1} = 0{\cdot}165$.

$\therefore \mu = 1{\cdot}004$

and the bending will be practically negligible.

(2) Take $\lambda = 1{,}000$, the other constants remaining the same,

then $p = 2\pi \times 3 \times 10^5$, $\sigma_1 = 9 \times 10^5$, $\dfrac{pk_1}{\sigma_1} = 0{\cdot}333$, $\dfrac{p(k + k_1)}{\sigma_1} = 0{\cdot}50$.

$\therefore \mu = 1{\cdot}067$.

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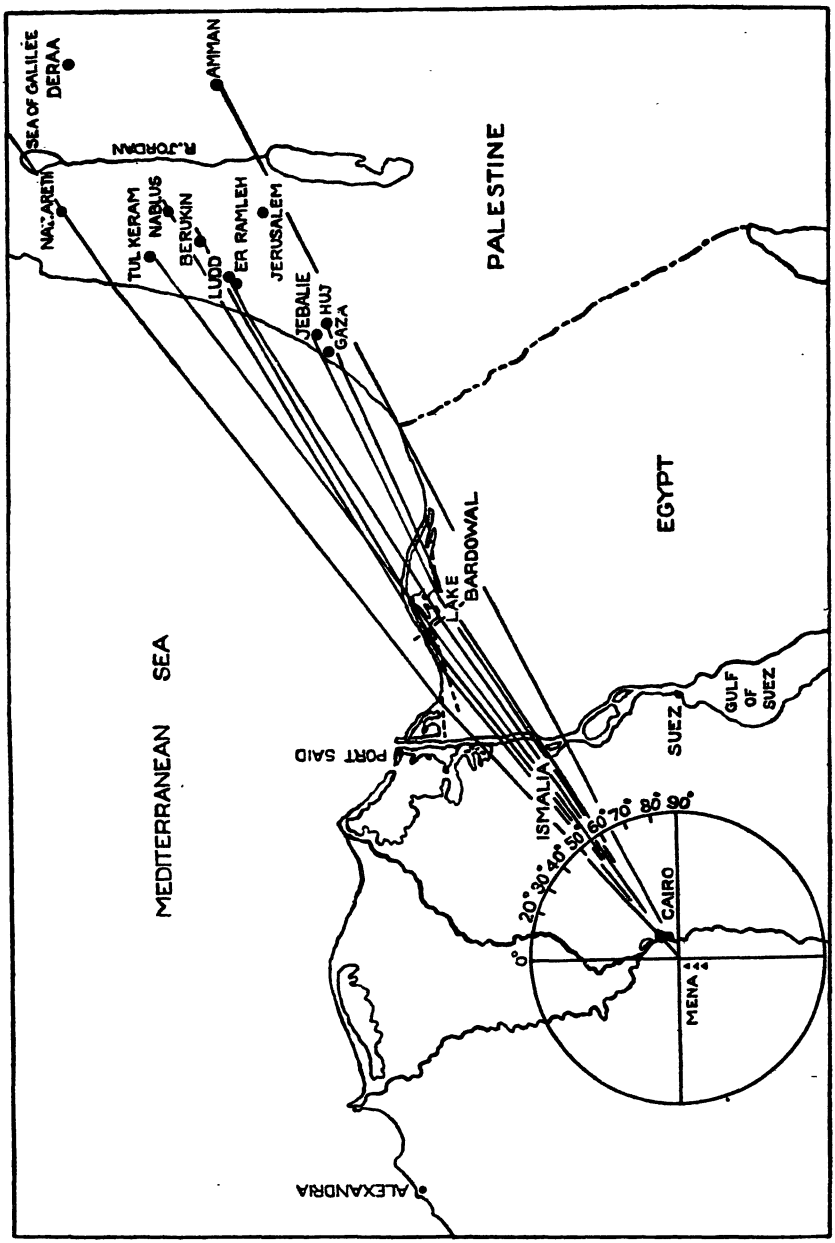

FIG. 3.—Chart showing paths of the waves.

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This is a rather larger value than is actually found, *i.e.*, 1·02, but a larger value of σ is probable on the Cyprus coast than 9×10^5 which is a probable value for the more resistive dry sand of the Sinai Peninsula.

Another set of observations on this refraction is illustrated in Fig. 3, which is a map of the Egyptian and Palestine coast line.

The bent lines represent the probable directions of the rays of electromagnetic waves from the various known stations in the Palestine area, to the direction-finding receiving station near Cairo.

It will be seen that the observed bearing is in nearly every case too small by amounts which are nearly as much as 4° in some cases. These systematic errors in bearings were noticed some while before the explanation was arrived at, and there is therefore no hint of a forced agreement.

The observed bearings were in practically every case the mean of a very large number of observations extending over several months.

A graphical method of trial and error was employed in finding the path of the rays. A value for μ the ratio of the velocity over sea to the velocity over land was chosen, and then, starting from the known mean bearing of a given station, it was possible to map out the path of the ray. If the ray passed to one or other side of the place at which the station was known to be situated the value of μ was corrected to give a closer approximation.

In this manner a mean value of $\mu = 1{\cdot}05$ was determined.

This value is considerably greater than that determined from the Cyprus bearings, *i.e.*, 1·02, but this is a result to be expected as the desert sand of Egypt and Sinai has a much higher specific resistance than the soil of Cyprus.

The rays all pass very close to the known positions of the stations.

It must be remembered that the same value of μ is used for all the rays, and that this quantity has not been adjusted in each case to make the ray pass through the station. The results therefore indicate a fairly close agreement with theory.

Unfortunately practically all the rays cross the coast line of the Sinai Peninsula at Lake Bardowal; the coast line of this lake is so irregular, and so cut up with pools and swamps, that it is very difficult to determine the exact mean coast line where the ray crosses it. A fairly reliable estimate has been made with the help of 1/40,000 map of the district, but naturally it is difficult to avoid choosing the coast line so as to give good results.

The curve (Fig. 4) gives the errors at various stations, arranged in order of their bearings.

The most striking feature of this is that the mean error on the station at Tul Keram is zero, while the errors on the rest of the stations in this neighbourhood are about 4°.

This is not an accidental error or effect, for it is reproduced month after month, the probable error deduced from the discordances being less than ½°.

This anomaly can be readily explained if we examine the coast line. At the point where the great circle joining Tul Keram and Cairo crosses the coast at Lake Bardowal the coast line curves round so that it is cut practically normally by this ray, and there is therefore no bending, and the ray pursues a straight path. The slightest change in the position of the transmitting

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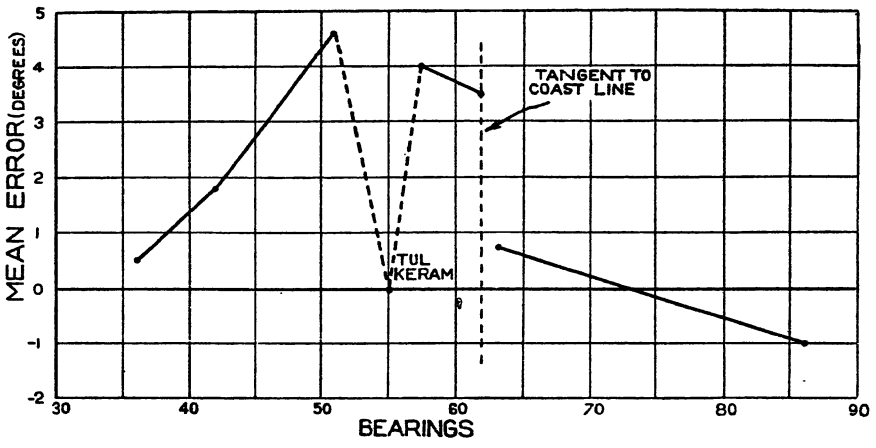

FIG. 4.

station shifts the direct ray to a point where it crosses the coast line at an acute angle, and distortion will again appear.

Perhaps it is not wise to press this explanation too far, but it is difficult to find any other adequate explanation of what is otherwise a very striking anomaly.

Another point of interest is in connection with the transmitting station at Amman. It will be noticed that the direct ray from Amman to Cairo (Figs. 3 and 5) is tangential to the coast line, and since there is no crossing of the coast line this will be a possible ray. At the same time another ray bent at the coast line at C and D (Fig. 5) is also possible. The waves arriving by the two paths AM and ACDM will be out of phase and travelling in different directions and will, in general, produce a rotating field, and a bad minimum on the direction finder will ensue. This result was quite marked at the receiving station at Cairo, and was one of the cases in which there was a really bad minimum in the daytime. This theory was further confirmed in a striking way as follows :—

Two stations were erected at Cairo, about 500 yards apart, and the mean bearings of Amman from these stations were 59° and 54·5° respectively (the difference 4·5° is well outside the limits of the probable errors); the true bearing is 63°. The difference is explained when we observe that the difference in optical length, *i.e.*, in phase of the two rays, is very different at the two stations (in spite of their nearness), resulting in a large difference in the mean direction of the resultants, *i.e.*, the bearings.

WAVELENGTH.

It was shown on page 423 that on this theory the amount of refraction should depend very greatly on the wavelength of the transmitted wave. This result is again confirmed by observation. The bearings of the big power station at Damascus are of interest in this connection.

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These are all very consistent on a 2,600 metre wavelength, and average 50·5°, which is the true bearing of the station, so that there is no error in spite of the fact that other stations, on the same mean bearings working on wavelengths of 600 to 1,000 metres, have errors of 3° or 4°. This effect cannot be ascribed to peculiarities of the coast line which is quite definite at the point where the ray crosses it.

The small station at Damascus working on $\lambda = 1{,}000$ gives a mean bearing of 46°, although at the greatest there cannot be more than 1° difference in the direction of the two stations.

These results show quite definitely that the long waves ($\lambda = 2{,}600$) sent out by the big station are not refracted, while the short waves ($\lambda = 1{,}000$) are bent at the coast; this is further confirmed by the fact that when the

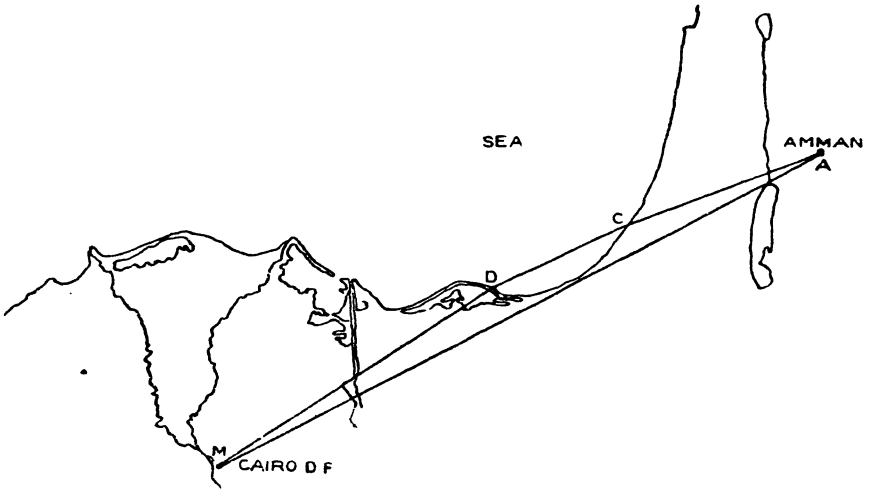

FIG. 5.

big station started working on a wavelength of 1,200 bearings as low as 47° (sharp minimum) were obtained.

This variation in the amount of distortion it will be remembered is in complete accord with the theory.

Perhaps the most interesting example is one which shows that the Germans were behind us in this respect and were still unaware of this refraction. In the final advance in Palestine some records of the German bearings from a direction-finding station at Tul Keram were captured. The mean bearings on some of our known stations were calculated, and are tabulated on page 428.

Bearings on Port Said and Alexandria are very nearly correct, it therefore appears probable that the D.F. station was set on these known stations, so that the error should be zero in these directions. The error on the other unknown stations was then — 6° or — 7°. If the station was set up in this

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	SUB Port Said.	SUH Alexandria.	Ramleh.	Jerusalem.
Mean observed bearing .	246·75	257·5	197·8	155·5
Number of bearings . .	33	21	82	75
True bearing . . .	246·5	257·5	204·5	161·5
Error.	0·25	0	−6·7	−6·0

manner then the errors on the inland stations can be readily explained, Fig. 6. On account of the refraction, the apparent bearings of Port Said and Alexandria should have been 6° or 7° too great if the station had been oriented properly (due north and south) at the start. By setting on these known stations the Germans introduced an error in the station of — 6° or — 7°

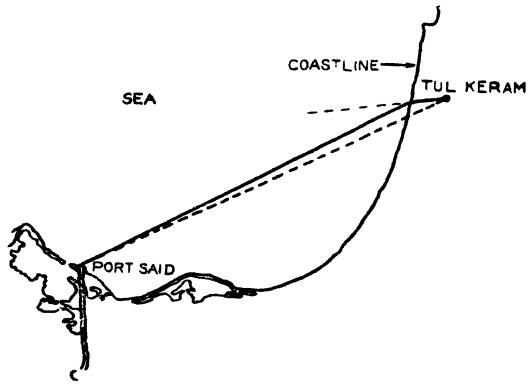

FIG. 6.

which showed up at once on inland stations for which the rays are all the way over land, as is the case with the two stations cited.

It therefore seems probable that there was very marked refraction at the coast line, and that the Germans were entirely unaware of it.

SUMMARY.

Direct observations are shown which go to prove that there is a systematic bending of rays which cross a coast line, and that this " bending " behaves as if it were due to a " Refraction " on account of the different wave velocities over sea and over land.

Further observations are cited confirming this point and agreeing in general with the theory of propagation of electric waves over land given by Zenneck, Hack, Sommerfeld and others.

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A Form of Inductionless High Resistance.*

By N. W. McLACHLAN, D.Sc.(Eng.), M.I.E.E.

DESCRIPTION OF RESISTANCE.

A solution of cadmium iodide in amyl alcohol has been used at the National Physical Laboratory as a form of high resistance for many years.† As a general rule resistances of the order of 50 megohms or more have been utilised for direct current work. The specific resistance of the cadmium solution is so high that the inductive effect due to the geometrical configuration of the resistance is small enough to be neglected in resistances of the order of 0·1 to 0·3 megohm, these being the limits required in the tests for which the resistance was used. There might be an electrolytic variation with frequency, and experiments conducted to investigate this point are described below. The results of these experiments showed that the resistance was independent of the frequency up to 80,000 cycles per second, this being the highest frequency attained.

The form of resistance adopted is illustrated in Fig. 1. This design was chosen because of its compactness, but the tube can easily be modified and made straight if desired. This would, of course, be less inductive than the form shown. To avoid capacity effects, the cadmium electrodes should not be too near together. The specific resistance of the liquid varies with time, but the sample used in these tests had been in the laboratory for over ten years, and had probably attained a fairly constant value for any particular temperature. At 15° C. ρ was about $1{\cdot}4 \times 10^4$ ohms per cm. cube, but it depended on the strength of the solution.

The resistance shown in Fig. 1 is fixed in magnitude, but a variable resistance is merely a matter of design. One of the chief points is to prevent access of moisture, and evaporation of the liquid. A straight tube with a fixed electrode at the bottom and a movable one at the top could be adopted. The latter electrode would be adjusted by means of a glass tap with a groove, on which a thin cable suspending the electrode was wound. Or the electrode could be fixed and a glass rod lowered into the tube, thus varying the cross-sectional area of the liquid.‡ If there were no variation with time, the resistance could be read off by calibrating the tube, which could be immersed in a bath to preserve constant temperature.

METHOD OF MEASUREMENT.

The method of measuring the resistance using alternating currents is an adaptation of the Wien bridge suggested by Mr. D. W. Dye. The bridge accomplishes in one stage what the present substitution method does in two stages. The reason for not using the bridge is its limitation to acoustic frequencies, unless modifications are introduced with regard to the detector. The resistance under examination is used as a shunt to a condenser (see

* Paper received in final form February 13th, 1920.

† See N.P.L. Report for 1907. This particular solution was first used by Hittorf for high non-polarisable resistances.

‡ See F. W. Jordan, RADIO REVIEW 1, p. 173, January, 1920.

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Fig. 2), the latter forming part of a resonance circuit. This circuit is loosely coupled to a valve generator circuit, the current and frequency in which are kept constant during any one set of tests. The condenser in the former circuit is adjusted till resonance is obtained and the reading of the thermo-ammeter A is a maximum. The shunt resistance is then removed and a

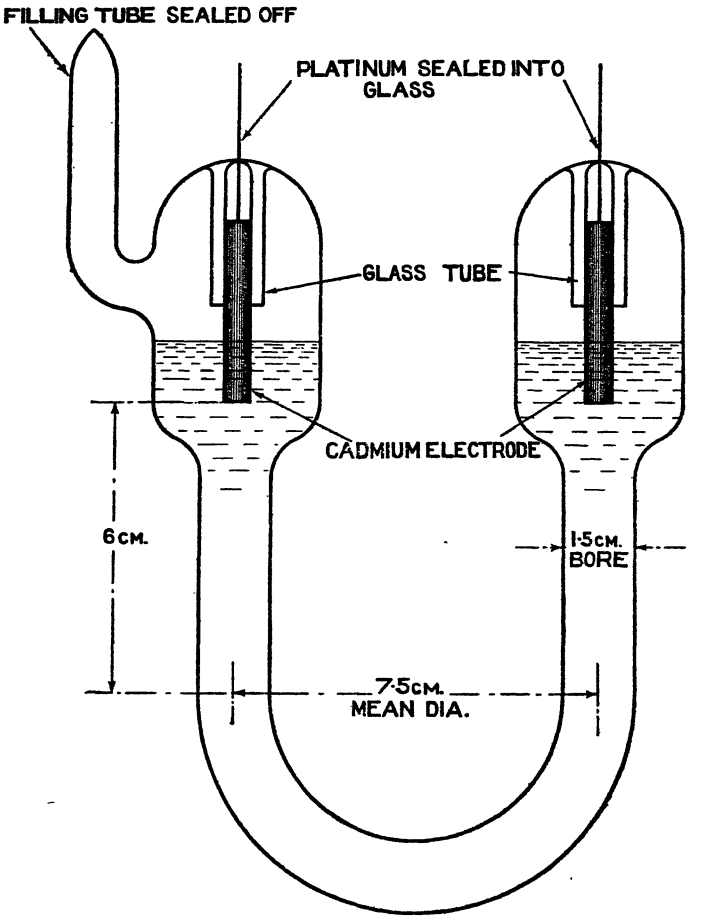

FIG. 1.

non-inductive resistance of small magnitude connected in series with the condenser (see Fig. 3), and adjusted until the reading of the thermo-ammeter at resonance is equal to that obtained in the previous experiment. If the high resistance has appreciable capacity, the condenser readings will be different in the two cases, the new value C being given by $C = C_1 + C_2$. In these experiments the capacity C_2 was negligible. Using the symbols of Figs. 2 and 3, it can be shown, by considering the impedance of the

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condenser and shunt resistance, that $R = \frac{1}{\omega^2 C^2 R_{eq}}$, provided $\frac{1}{\omega^2 C^2 R^2}$ is much greater than unity.

The resistance being independent of the frequency up to 80,000 cycles per second, as stated before, its value when used in conjunction with the

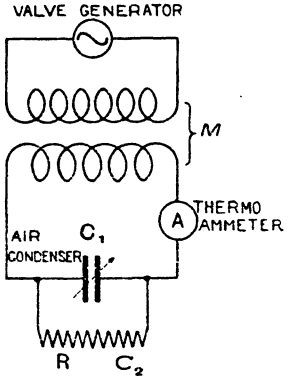

FIG. 2.

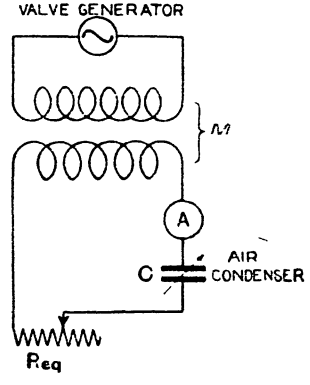

FIG. 3.

magneto (see below) was found by means of a megger. Since the solution is non-polarisable, a direct current generator can be used as a source of E.M.F. for the megger. Thus the actual value of the resistance can be found to within 1 or 2 per cent. immediately after it has been used. In this way allowance is made for any temperature rise which may occur.

USE OF RESISTANCE.

The necessity for an inductionless high resistance arose in carrying out research work on magnetos. The function of the resistance, when connected from the H.T. secondary lead to earth, in parallel with some form of spark gap, is to cause a leakage simulating that of a sparking plug when used in an engine. In this case the insulating properties of the plug are impaired by sooty deposits and temperature elevation. When testing a magneto, the gap is fixed and the resistance adjusted until regular sparking ceases. The value of the resistance to effect this is a measure of the capability of the magneto to withstand adverse plug conditions. This procedure is usually termed a "utility test."*

CONDITIONS TO BE FULFILLED.

A resistance for the above purpose must fulfil at least two conditions: (1) It must be inductionless up to frequencies of 20,000 cycles per second, because the magneto discharge is oscillatory; (2) It must have a large surface and volume to cope with the energy loss due to the passage of current from the magneto. This is important owing to the large temperature coefficient of the liquid. Although temperature variation can be dealt with as shown above, it is preferable to have as small a variation as possible.

* See A. P. Young and H. Warren, "The Process of Ignition." Paper before Inst. Automobile Engineers, February 4th, 1920.

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Automatic Sending Device Installed in the Alipur Observatory, Calcutta,

For Sending the International Time Signals from the 30 K.W. Calcutta Radio Station.*

The instrument here described was designed and manufactured in the Indian Government Telegraph Workshops in Calcutta.

Essentially it consists of a wheel H, Fig. 2, 10 inches in diameter, rotated uniformly at a speed of 1 r.p.m. through worm gearing by a phonic motor driven by a vibrating reed, and carrying on its periphery brass contact strips let into ebonite.

The motor is in fact one used for the "Murray" drive as applied to the distributor of the Baudot printing telegraph system.

The arrangement of the brass contacts is shown in Fig. 1. Two brushes rest on the contacts. One, X, controls the sending key in the radio station and the second, Y, controls a pen on a chronograph and registers sixty beats to each revolution of the wheel.

A second pen on the same chronograph registers seconds beats from the observatory standard clock.

From this chronograph record, therefore, the observer can readily see whether the time sending apparatus is keeping correct and take steps if necessary to keep it so. Two adjustments are available for this latter purpose and will be described hereafter.

The first brush X is traversed across the periphery of the wheel so as to send the appropriate signals for each minute.

This brush is carried on a sliding sleeve B, Figs. 2 and 3. Connected to the sleeve is an arm D, which engages with the worm W by means of a pin. As soon as the brush X has finished the last signal the pin runs out into a shallow groove in the worm next the wheel D, and thereby raises X out of contact with the wheel.

The brush X can be set by means of a scale to make contact at any time from one second before to one second after brush Y.

The time wheel is started electrically by an impulse from the pendulum of the standard clock given at the second before three minutes to the correct time calculated after allowing for the lag in the land line and apparatus connecting the observatory to the wireless station.

This lag is of the order of two-tenths of a second.

The adjustment on brush X allows for any fraction of a second. For example, suppose the correct time to start the signal has been determined to be 7 hours 29 minutes, 36·4″, by the standard clock, the time wheel must start at 7 hours 29 minutes 36·2″, allowing 0·2″ for the lag. The clock will start the wheel at 7 hours 29 minutes 36″, and the brush X must be adjusted to make contact 0·2″ later than Y.

* Communicated by the Director-General of Posts and Telegraphs, India, January, 1920

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Automatic Wireless Time Sender Installed in the Alipur Observatory, Calcutta.

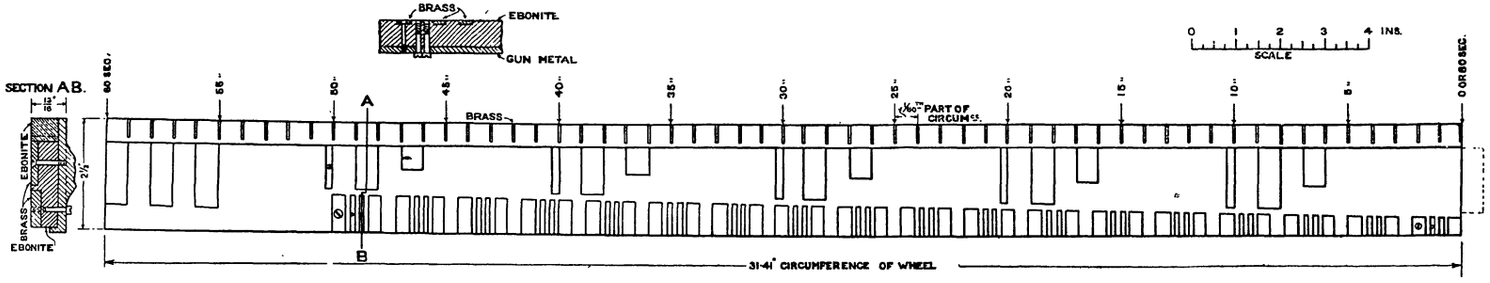


FIG. 1.

FIG. 1.—Arrangement of Contacts on Periphery of Wheel H.

FIG. 2.—Elevation and Section of Transmitting Wheel.

FIG. 3.—Plan of Apparatus and Diagram of Connections.

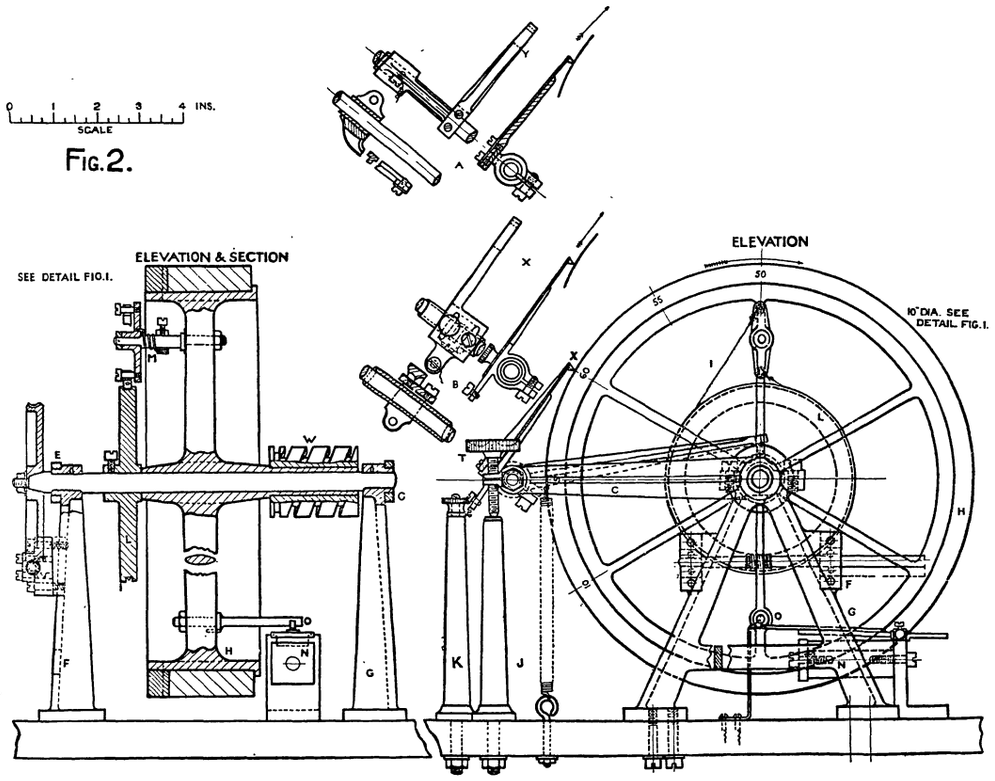
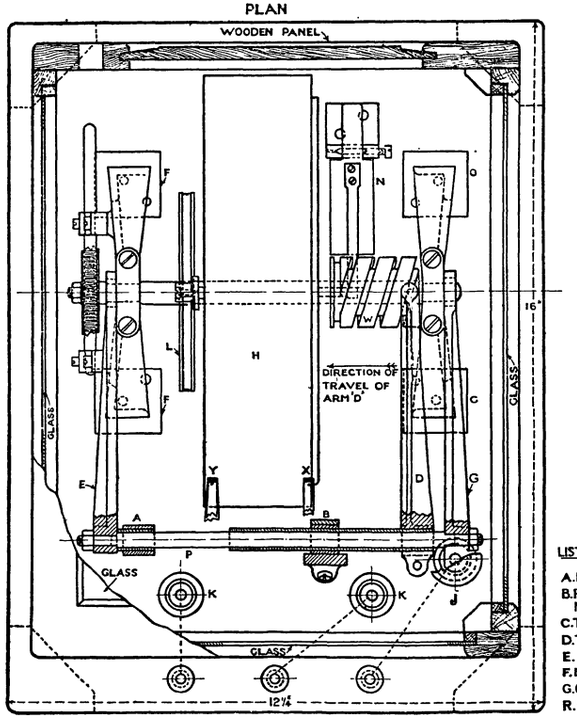


FIG. 2.



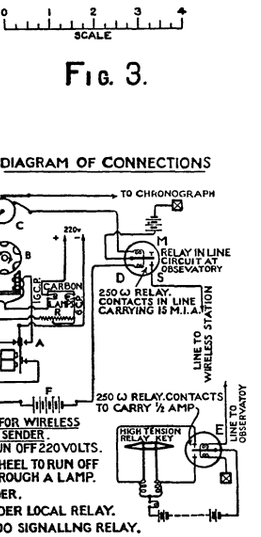

0 1 2 3 4
SCALE
DIAGRAM OF CONNECTIONS
TO CHRONOGRAPH
220v
RELAY IN LINE CIRCUIT AT OBSERVATORY
CARBON
250 Ω RELAY. CONTACTS IN LINE CARRYING 15 M.I.A.
LINE TO WIRELESS STATION
250 Ω RELAY CONTACTS TO CARRY ½ AMP
HIGH TENSION RELAY KEY
LINE TO OBSERVATORY
LIST OF GEAR FOR WIRELESS TIME SENDER
A. REED TO RUN OFF 220 VOLTS.
B. PHONIC WHEEL TO RUN OFF MAINS THROUGH A LAMP.
C. TIME SENDER.
D. TIME SENDER LOCAL RELAY.
E. DO DO SIGNALLNG RELAY.
F. BATTERY.
G. CHARGING BOARD FOR 'F' WITH LAMP.
R. REED CONTROL RHEOSTAT.

FIG. 3.

(*To face p.* 432.)

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The time wheel H is loose on the spindle rotated by the phonic motor wheel and is connected to it by a friction clutch. The latter consists of a steel chain I, embracing the friction drum L, and held tight by a spring M, Fig. 2.

The time wheel is set ready for commencing the time signal by engaging the stop O with the armature of the electromagnet N.

When the phonic motor is started the clutch slips allowing the worm wheel and spindle to turn idly until the electromagnet N releases the time wheel and allows it also to rotate.

When the time wheel is in the starting position brush Y is set to make contact with the sixtieth second contact and brush X is set to make contact the appropriate fraction of a second before or after Y.

The brush carriers A and B are supported on a cross rod P, Fig. 3, clamped to the radial arms C and E, which swivel about the axle and supports of the time wheel. A milled screw T, resting on the pillar J, enables the whole brush gear to be moved simultaneously to advance or retard both brushes relatively to the time wheel.

When the time wheel is latched ready to start it is by means of T that brush Y is set to make contact with the sixtieth segment. From this position the screw T is long enough to permit of the brushes being advanced or retarded one second.

Since Y is making contact with a "second" segment when the impulse from the clock pendulum starts the time wheel, both records on the chronograph, one from the time wheel and one from the standard clock must coincide to begin with. If they commence to get out of step adjusting T will bring them back again provided the reed driving the phonic motor will keep time to within one second in three minutes. This presents no difficulty in practice. The screw T therefore is the first of the two adjustments referred to previously.

The second adjustment is provided in a rheostat inserted in series with the driving magnet of the reed.

The reed will run slightly faster with a small than with a large amplitude. The voltage on the mains may also vary.

The rheostat allows for both. The rheostat is set in mid-position and the reed is then weighted and the position of the weight carefully adjusted till the phonic motor runs at the correct speed. In practice this is done by watching the record of the time wheel on the chronograph. After this adjustment the position of the weight need not be touched, slight readjustments being made by means of the rheostat.

In adjusting the apparatus to send time the phonic wheel is set running fifteen minutes before time and the reed-rheostat altered till the two records on the chronograph coincide within one-tenth of a second or less in a minute. This usually needs little or no adjustment. After this has been verified and if necessary adjusted the apparatus can be set ready to start knowing that the adjusting screw T will provide sufficient margin to keep the two records in synchronism till the end of the three-minute signal.

Mention has been made previously of starting with brush X, making

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contact earlier than Y. This is done only when it is necessary to start at 60″ as the electrical impulse at the sixtieth second is missed by the clock for counting purposes. In this case although the true time to start might come between the sixtieth and first seconds it becomes necessary to start at 1″ and arrange for X to make contact early. For starting the apparatus the observer is provided with a key which in its rest position joins the clock pendulum circuit to the chronograph and when pressed joins it to the starting electromagnet. No great accuracy is required on the part of the observer as all that is necessary is to press the key any time after the second before time and wait till the pendulum on its next swing gives the impulse which starts the time sender. Then for three minutes the observer must watch the two records on the chronograph and if they commence to differ bring them into synchronism again.

In Fig. 3 is given a diagram of connections. The high-tension relay key is the sending key on the secondary side of the transformer in the wireless station.

Electronic and Ionic Oscillations in Thermionic Valves.

By THE EDITOR.

The use of the three-electrode thermionic valve as a generator of continuous oscillations has been known since 1913 and a great number of circuit arrangements have since been devised for the purpose. This application of the three-electrode valve has been one of the principal factors in the recent developments of radiotelegraphy and more especially of radiotelephony. At this moment, however, we wish to refer to some phenomena of a different type, of little practical importance it may be at the present moment, but of undoubted interest to all students of the thermionic valve. In the November issue of this REVIEW (page 53) Professor Whiddington described a circuit arrangement, containing neither inductance nor capacity, which gave, however, a sustained oscillation of a definite frequency. The circuits were of the simplest character; a plate battery connected as usual between the filament and the plate, and a grid battery with potentiometer connected between the filament and the grid. The valve employed was soft and it was shown that the frequency obtained depended on the nature of the remanent gas, on the grid voltage and on the distance between the filament and the grid. Professor Whiddington explained the phenomenon by assuming that bursts of electrons occur from certain spots on the filament which have abnormally high emissivity and that these electrons travel to the grid in a certain definite time depending on the grid potential, the distance between the filament and the grid, and the ratio of the charge of the electron to its mass. After passing through the grid they are accelerated in the stronger field due to the plate voltage and soon reach such a velocity

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that they ionise the molecules with which they collide and thus produce positive ions which travel towards the filament with a velocity depending on the ratio of their charge to their mass. This ionic bombardment causes the filament to emit a fresh outburst of electrons and the cycle commences *de novo*. The period is the sum of the times taken by the outward excursion of the electron and the subsequent inward excursion of the ion, and these times, of which the latter is by far the greater, depend on the potential difference between the grid and the filament. Now with a four-volt filament and one volt on the grid this potential difference varies along the filament from + 1 to — 3 volts. The specially emissive spot on the filament is a very ingenious assumption to explain the definiteness of the frequency observed in spite of this range of the potential difference. Professor Whiddington's paper is of the nature of a preliminary announcement, but the agreement obtained between the observed frequencies and those calculated on the assumption that the ions concerned are those of mercury is very striking, and, as he says, the paper introduces a new and at first sight rather astonishing phenomenon.

In the *Physikalische Zeitschrift* for January 1st of this year a paper was published by Barkhausen and Kurz describing experiments of a somewhat similar character. They used hard valves and obtained oscillations due to the electrons alone. Professor Whiddington had calculated the wavelength for this case as 77 cm. for one volt on the grid of the valve employed by him, but had not apparently obtained such short waves experimentally. Contrary to the usual practice Barkhausen and Kurz applied a high positive potential to the grid and a smaller negative voltage to the plate. Under these conditions every electron emitted should pass to the grid and no current should flow in the plate circuit, unless some gas be present, which being ionised by the electrons would cause a flow of positive ions to the negative plate. In some experiments, however, it was found that this reverse current was not obtained, but that with — 100 volts on the plate the ammeter in the plate circuit indicated a current entering the valve at the plate and thus charging the plate battery. This was ultimately found to be due to internal oscillations of such a magnitude that electrons reached the plate in spite of its negative potential. After ordinary methods had failed to indicate any oscillations it was found by connecting parallel wires to the plate and grid, that stationary waves were maintained with a wavelength of about 1 metre and a frequency therefore of 300 million. Inductances and capacities outside the tube were found to have little effect, but the wavelength was reduced from 2·14 to 1·31 metres by increasing the filament heating current from 0·8 to 1·15 amperes and from 2·4 to 1·04 metres by changing the plate voltage from + 4 to — 300 volts. An increase of grid voltage also reduced the wavelength. The variations of wavelength are not uniform, however, but exhibit irregularities suggesting some resonance effect. A most important fact is that although these phenomena were obtained with three different valves with cylindrical anodes and axial filaments, no trace of such oscillations could be found in valves with parallel plane anodes. Even with cylindrical anodes, oscillations were only obtained

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in valves with closely-coiled fine grids. As Barkhausen and Kurz observe, these oscillations must be due to the electrons moving from the filament to the grid with a high velocity, passing through the grid, then brought to rest at a rate depending on the plate potential, then returning with increasing velocity, passing through the grid, being again brought to rest by the field between the grid and the filament, and so on. What the controlling mechanism may be, whereby the electrons are constrained to move to and fro in the same phase, the authors cannot explain. It may be that the bombardment of the filament by the returning electrons of an incipient oscillation causes an increased emission which tends to amplify the succeeding oscillation, although the space charge effect would tend to reduce the emission. The increase of frequency with increased filament current is presumably due to increased space charge which causes the returning electrons to slow up more rapidly as they approach the filament. It is possible that the phenomenon may involve in some way the emission of secondary electrons or δ rays as in the Dynatron. With 500 volts on the grid, the electrons striking it will certainly cause such an emission, but the emitted electrons will be unable to move far from the grid in such a powerful field. The shortest waves were obtained with a Schott-K valve with an anode of 2·1 cm. diameter with 500 volts on the grid and the highest possible filament current. The wavelength was 43 cm., but in the opinion of the authors a wavelength of 10 cm. or even less could be obtained by using suitable valves with very high grid voltages.

We have discussed these two papers at this length because they appear to call for further investigation. They certainly constitute an important addition to the already long list of contributions which the three-electrode valve has made to scientific progress.

An Automatic Call Device.*

By Major BASIL BINYON, B.A., O.B.E.

At the present time oral reception of wireless signals has come to be so generally applied that it is difficult to conceive of a mechanical machine capable of having the selectivity and sensitivity such as that possessed by the ear and the brain. The apparatus described is designed to operate with Morse signal calls of three or four letters, and does not require the use of any special code. The set comprises two units in addition to the ordinary wireless receiver, (1) a Turner valve relay,† and (2) the selector mechanism. The latter is the invention of Mr. Shepherd. The Turner relay responds to all signals of sufficient strength, and of the correct wavelength, and moves the selector mechanism one space for each such signal whether dot or dash. The selector comprises a number of contact springs arranged radially round the driving shaft which is controlled by the Turner relay. These springs are sorted out by a special mechanism so that they pass either above or below a fixed contact ring depending upon whether a dot or a dash is received. By connecting up the contacts on this ring in the appropriate manner, the alarm bell circuit will be completed when the proper arrangement of contact fingers is obtained by the signal that it is desired should operate the apparatus.

* Abstract of Paper read before the Wireless Society of London on April 30th, 1920.

† For description of this relay see *Journal of the Institution of Electrical Engineers*, 57, Supplement, pp. 50—65, April, 1920.

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The apparatus is normally set to respond to "S.O.S." calls and calls for the receiving ship or station. The alarm bell is also rung should any one of the valves burn out. A drop indicator on the apparatus indicates whether the bell-ring is due to failure of a valve or whether it is a call for the ship, or a distress call.

A very successful demonstration was given of the apparatus working on a receiving aerial.

Thermionic Valve Nomenclature.

Barkhausen has suggested the following symbols for the various quantities arising in connection with three-electrode thermionic valves. These suggestions may prove of interest to English workers interested in the subject of valve nomenclature and symbols.*

Magnitudes in the anode circuit	Subscript a
„ „ grid circuit	„ g
„ „ heating circuit	„ h
Power before amplification [unverstärkt] . . .	„ u
„ after amplification [verstärkt] . . .	„ v
Momentary value of total current	i
„ „ „ voltage	e
Mean value of current	I
„ „ voltage	E
Momentary value of superposed alternating current .	$\mathfrak{i}$
„ „ „ „ voltage .	$\mathfrak{e}$
Maximum value of superposed alternating current .	$\mathfrak{J}$
„ „ „ „ voltage .	$\mathfrak{E}$
The characteristic:	$I_a = f(E_g)$ with constant E_a
The grid-current characteristic:	$I_g = f(E_g)$ „ E_a
The anode-current characteristic:	$I_a = f(E_a)$ „ E_g

Steepness [Steilheit]: $S = \left(\frac{\partial I_a}{\partial E_g}\right)_{E_a}$

Voltage ratio [Durchgriff]: $D = -\left(\frac{\partial E_g}{\partial E_a}\right)_{I_a}$

Internal resistance: $R_i = \left(\frac{\partial E_a}{\partial I_a}\right)_{E_g}$

$SR_iD = 1$

Emission current: $i_e = i_g + i_a$; $(I_e = I_g + I_a)$.

Saturation current: I_s = limiting value of I_e

Ratio of power amplification [Verstärkungsgrad]: $W = \sqrt{\frac{N_v}{N_u}}$

(N = Power).

* For further suggestions relative to Triode Nomenclature see correspondence on the following pages of the RADIO REVIEW: W. H. Eccles, p. 211 (January); L. B. Turner, p. 314, E. V. Appleton, p. 316 (March); E. V. Appleton, p. 368 (April); C. L. Fortescue, p. 417 (May); and A. Press, p. 472 (June).

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Review of Radio Literature.

1. Articles and Patents.

396. ON THE THEORY OF RADIOTELEGRAPHIC AND RADIOTELEPHONIC RECEIVER CIRCUITS. J. F. J. Bethenod. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 517—525, October, 1919.)

A mathematical investigation of the values of the radio frequency and audio frequency currents obtained in a two-circuit inductively coupled receiver with the customary arrangement of a detector possessing a non-linear voltage-current characteristic.

397. DETERMINATION OF RATE OF DE-IONISATION OF ELECTRIC ARC VAPOUR. H. G. Cordes. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 527—539, October, 1919.)

A theoretical discussion of an oscillatory circuit method of determining the rate of de-ionisation and the effect of this rate on the voltage required for a subsequent re-ignition.

398. THE DESIGN OF POULSEN ARC CONVERTERS FOR RADIO TELEGRAPHY. L. F. Fuller. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 449—497, October, 1919.)

Deals exhaustively with the design of high power arc sets (100 kilowatt and over) from the engineering standpoint. A detailed summary of the radio cycle of operations based on the theories of Barkhausen and Pederson is first given from which it is possible to deduce certain relations which are in accordance with experiment. The effective value of the voltage across the arc which is useful in circulating the oscillatory current I_s is shown to be equal to the difference of the two effective values during the two halves of the I_s cycle. This quantity E_ϕ is equal to $I_s R_s$ where R_s is the oscillatory circuit resistance. Experiment shows that when an arc is operating under good conditions its effective direct current resistance is equal to the resistance of the oscillatory circuit. From this it may be shown that the peak value of E_ϕ is equal to the direct voltage E_{da} maintained across the arc by the D.C. generator. It is also shown both analytically and experimentally that the voltage across the arc E_a is equal to $1{\cdot}4\, E_{da}$. These experiments were carried out at Palo Alto using a radio frequency voltmeter consisting of a hot wire milliammeter in series with a non-inductive resistance across the radio frequency terminals of the arc for the measurement of E_a, E_{da} being calculated from a knowledge of the electrical magnitudes of the direct current circuit.

The theory of the effects of the magnetic flux B_g upon extinction and ignition is worked out by considering the effect of B_g on I_s. It is found that there is an optimum value of B_g. For values less than this the gap ionisation

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is above normal and the effective value of E_a is decreased and thus I_s is decreased.

If B_g is above the optimum value β_g, although the extinction and ignition voltages are abnormally high the time of extinction is advanced and ignition is delayed. Such improper timing tends to produce harmonics.

The Poulsen cycle efficiency may be calculated from the following:

$$\text{Arc output} = R_s I_s^2 = \frac{E_{da} I_d}{\rho^2}$$

where $\rho = \frac{I_d}{I_s}$ and I_d is the direct current through the arc.

$$\text{Arc input} = E_{da} I_d.$$

$$\therefore \text{ Arc efficiency } \epsilon = \frac{1}{\rho^2}.$$

If $\rho = \sqrt{2}$ (as is shown to be the case in the preliminary discussion of the circuit theory) $\epsilon = 50\%$. This is the highest theoretical efficiency.

As a certain fraction of each radio frequency cycle is allowed for the extinction of the arc we may say that the length of the time required for this is inversely proportional to the frequency. Thus as the rate at which the ions are removed is dependent on the field strength we may write

$$\beta_g \propto \frac{1}{\lambda}.$$

The necessary field strength is also shown to be inversely proportional to the molecular velocity of the ions, and if it be assumed that the absolute temperature of the arc flame is proportional to the power input $E_{da} I_d$ we may write

$$\beta_g = \frac{K \sqrt{E_{da} I_d}}{\lambda}$$

where K is found to be 4·25 for kerosene and 8·50 for ethyl alcohol. Experimental data in support of this formula are given.

The use of high power converters necessitates the design of electromagnets up to a weight of 80 tons. In the search for a theoretical basis for design the work of Ewing and Weiss is considered but is not found suitable in this case where fields of 2 to 20 kilogauss are contemplated. Direct experiment seemed the only basis for design. It is shown from practical data that the best value for the tip-gap ratio (ratio of diameter of tip to thickness of gap) is $\sqrt{3}$ though small departures from this value do not seriously affect the flux density.

The best type of pole tip should start with an angle of 60° near the gap, changing to 55° part way down the cone and finally changing to 50° near the base of the cone (approximately one-third of the slant height for each angle).

The pole-gap ratio (ratio of pole diameter to thickness of gap) is important as being the main factor controlling the weight and cost of an arc converter. The magnetic circuit should be designed so that the knee of the saturation curve is reached at rated full load current. Experimental data show that

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the value of magnetic flux when the knee of the curve is reached does not increase much for values of the pole-gap ratio higher than 12. However, considerations of cost and weight make it advisable to run the ratio at values lower than this, *e.g.* 8. The magnetic air gaps now in use range from 1 to 7 inches.

All modern arcs are provided with an area of chamber cooling surface approximately proportional to the arc rating. Data for this relation are given.

The carbon electrode should not be operated above 200 D.C. amps. per square inch. Carbon or graphite may be substituted for the copper anode of a Poulsen set but these materials have never come into regular use because a water-cooled copper electrode is less troublesome.

399. PRINCIPLES OF RADIO TRANSMISSION AND RECEPTION WITH ANTENNÆ AND COIL AERIALS. J. H. Dellinger. (*Proceedings of the American Institute of Electrical Engineers*, 38, pp. 1095—1150, October, 1919. *Bulletin of the Bureau of Standards*, 15, pp. 435—495. *Scientific Paper of the Bureau of Standards*, No. 354, December 11th, 1919. *Revue Générale de l'Électricité*, 7, p. 118D, April 10th, 1920, Abstract.)

This paper which is largely mathematical compares coil aerials with ordinary antennæ as regards transmission and reception. The formulæ obtained may be used in designing an aerial for any particular set of conditions. The conclusions reached have been verified by experiments. The advantages of the coil aerial as regards direction finding, prevention of interference, reducing strays, and in submarine work make the development of this aerial particularly important. The principal formulæ given are evolved from fundamental electromagnetic theory, and some of the most important results are as follows :—

Radiated magnetic field intensity from an antenna or condenser aerial,

$$H = \frac{2\pi}{10} \cdot \frac{h_s I_s}{\lambda d}.$$

Radiated magnetic field intensity from a coil

$$H = \frac{4\pi^2}{10} \cdot \frac{h_s l_s N_s I_s}{\lambda^2 d}.$$

Received current in an antenna or condenser aerial

$$I_r = 300 \frac{h_r H}{R}.$$

Received current in a coil

$$I_r = 600\pi . \frac{h_r l_r N_r H}{R\lambda}.$$

Distance at which a given current is received in a coil, for a given transmitting current in an antenna,

$$d = \frac{1184\, h_s h_r l_r N_r I_s}{R\lambda^2 I_r}.$$

Relative effectiveness of coil and antenna, for the same height and wavelength

$$d_c/d_a = N\sqrt{2\,(1 - \cos 2\pi l/\lambda)}.$$

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Relative effectiveness of coil and antenna, for the same height and wavelength, l small compared to λ,

$$d_c/d_a = 6{\cdot}28\,Nl/\lambda$$

Length of coil aerial equivalent to antenna of the same height

$$l = 0{\cdot}16\,\lambda/N.$$

Coil aerial reception factors.

E.M.F. reception factor $= a^2N/\lambda$.
Current reception factor $= a^2N/(R\lambda)$.
Voltage reception factor $= a^2NL/(R\lambda^2)$.

Radiation resistance.

$$R_a = (39{\cdot}7\,h/\lambda)^2 \qquad \text{(antenna)}$$
$$R_c = (13{\cdot}3\,a/\lambda)^4N^2 \qquad \text{(coil)}$$

Transmission formulæ were also given for antennæ and coils, identical with the ones previously published by the same author.*

The notation used in the above formulæ is as follows :—

Subscripts : s = sending ; r = receiving ; a = antenna ; c = coil.
I = effective value of current.
H = effective value of magnetic field intensity.
h = height of aerial.
d = distance along earth's surface from the sending aerial.
λ = wavelength.
l = horizontal length of coil aerial.
N = number of turns of wire on coil aerial.
a = length of side of square coil.
R = resistance of receiving aerial circuit.
L = inductance of receiving aerial circuit.

The results of the investigations show that the ratio of the ranges of communication with coil aerial and antenna is proportional to the number of turns, and horizontal length of the coil, and inversely proportional to the wavelength. The coil aerial is therefore particularly suitable for communication on short wavelengths. A coil aerial is quantitatively as powerful as an antenna only when its dimensions approach those of the antenna, but it is easier to make the resistance of a coil aerial small, thus making a small coil as effective as a large antenna. A small aerial as effective as the ordinary antenna may be secured without recourse to the closed coil principle, by using an aerial consisting of a condenser with two large parallel planes so arranged that the dielectric includes on ground.

400. ON THE SELF-INDUCTANCE OF SINGLE LAYER FLAT COILS.

S. Butterworth. (*Proceedings of the Physical Society of London*, 32, pp. 31—37, December, 1919.)

Two formulæ are given in this paper for the computation of the self-inductance of single layer flat coils, one for the case when the inner and outer radii are not very different and the other for the case of small inner radius. The two formulæ are shown to be consistent and capable of including all possible cases. From them it is shown that the inductance of such flat coils can be expressed in the form $L = Qn^2r^3$ in which n is the number of turns

* See RADIO REVIEW Abstract No. 4.

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per centimetre, r is the outer radius of the coil and Q a function of the ratio of the inner and outer radii. A table of this function follows :—

r_1/r_2	Q	r_1/r_2	Q	r_1/r_2	Q
0·00 ..	6·970	0·35 ..	5·996	0·70 ..	2·528
0·05 ..	6·964	0·40 ..	5·632	0·75 ..	1·946
0·10 ..	6·930	0·45 ..	5·213	0·80 ..	1·397
0·15 ..	6·845	0·50 ..	4·743	0·85 ..	0·8892
0·20 ..	6·728	0·55 ..	4·231	0·90 ..	0·4574
0·25 ..	6·544	0·60 ..	3·682	0·95 ..	0·1394
0·30 ..	6·300	0·65 ..	3·105	1·00 ..	0·0000

A table is also given in the paper for calculating the mutual inductances between flat coils.

401. AN EXPERIMENT ON IMPULSE EXCITATION. J. H. Morecroft. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 75—84, February, 1920.)

Oscillographic experiments on the effect of a unidirectional pulse on an oscillatory circuit are described. The oscillatory circuit of natural frequency 78·6 cycles per second was energised by direct current from a battery flowing through a portion of the circuit for a definite measurable time, the amplitudes and wave form of the exciting current and the current flowing in the oscillatory circuit being measured from simultaneous oscillograms. It is found that for the shortest time (0·002 second) of excitation used the amplitude of the first and second alternations of the oscillatory current are practically the same, and that the amplitude of the first alternation does not increase after the pulse has a length equal to one quarter of a cycle. As the pulse is lengthened the amplitude of the second alternation increases until the pulse length is half the natural period. For pulses lasting longer than one half period the amplitude of the second alternation decreases until it has that value which is fixed by the amplitude of the first and the decrement of the circuit. It is found that the greatest disturbance is produced in an oscillatory circuit by a rectangular pulse when this pulse has a duration equal to half the natural period of the circuit.

The effect of "infinite impedance" circuits when subjected to impulse excitation is studied and it is found that for pulses their filtering action is much less than for sustained waves of the same natural frequency as the "infinite impedance" circuit.

402. MEASUREMENT OF DIELECTRIC CONSTANT AT HIGH FREQUENCY BY THE WHEATSTONE BRIDGE. H. Joachim. (*Annalen der Physik*, 60, pp. 570—596, November 27th, 1919.)

A continuation of work published by Hertwig (*Annalen der Physik*, 42, p. 1099, 1913) but with various improvements which are fully described and

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discussed. The high frequency was obtained from a thermionic generator. The frequency employed in the tests was 10^6 ($\lambda = 300$ metres). Although heterodyne detection would have given greater sensitiveness, the author employed a rotary toothed ticker across the telephone receiver. Results are given for a number of inorganic salts and the variation of the constant with temperature is investigated and discussed theoretically. The variation of the constant with frequency is also discussed.

403. A METHOD FOR MEASURING VERY SMALL CAPACITIES AND INDUCTANCES. L. Pungs and G. Preuner. (*Physikalische Zeitschrift*, 20, pp. 543—545, December 1st, 1919.)

Heterodyne reception permits the detection of very small changes of frequency caused for example by the addition of small capacities or inductances. The use of the heterodyne principle for determining wavelength is stated to be due to Scheller. The authors propose the following method: two high-frequency circuits with thermionic generators ($f = 10^5$ to 10^6) produce beats (f about 1,000) which after rectification are superposed upon an alternating current of about the same frequency as the beats, produced by a third thermionic generator. This latter causes the beat tone to rise and fall in intensity, unless it has exactly the same frequency as the beat tone. The small capacity to be measured is connected in parallel with the condenser in the oscillatory anode circuit of one of the high frequency thermionic generators; it is then replaced by a known small capacity. If the latter is variable one can adjust until the tone is of constant intensity, if not one can calculate the capacity from the frequencies of the pulsating tone intensity. For further detail, the original paper should be consulted; the authors promise a further publication on the subject.

404. ELECTRIC ARC CHARACTERISTICS. E. Bräuer. (*Physikalische Zeitschrift*, 20, pp. 393—396, September, 1919. *Science Abstracts*, 22A, p. 567, Abstract No. 1538, December, 1919.)

The results of tests with various electrode materials for arcs are summarised in the form of a table giving the values for these various materials of the constants a and b in the equation of the characteristic; $ei = ai + b$, where e is the potential and i the current.

405. THE TELEPHONE RECEIVER: ITS MECHANICAL ACOUSTIC CHARACTERISTICS. W. Hahnemann and H. Hecht. (*Annalen der Physik*, 60, pp. 454—480, November 20th, 1919.)

A continuation of "Sound producers and receivers" (*Physikalische Zeitschrift*, 20, p. 104, 1919), and of "Sound fields and antennæ" (*idem*, 18, p. 261, 1917). From bridge measurements of the effective resistance and inductance of a receiver at various frequencies, curves are plotted of the power taken, both in a vacuum and in air with the earpiece at various distances from the diaphragm. The resonant frequency is changed by closing the

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sound opening and even by holding the receiver to the ear. The causes of the change of damping and of resonant frequency are discussed. From the resonance curves the damping is calculated in the usual way and from this the authors calculate the fraction of the power supplied which is converted into useful sound. For frequencies between 500 and 1,000 this is found to be from 0·1 to 1 per cent. The results are compared with those obtained by H. Abraham and M. Wien.

406. SPARK TRANSMITTERS. F. Lowenstein. (*French Patent* 497961, February 5th, 1919. Published December 23rd, 1919.)

The invention described in this specification consists in a multiple quenched spark gap apparatus for producing high frequency oscillations. The multiple gap is built up of a series of readily removable and replaceable units, each comprising one or more pairs of discs and electrodes with annular sparking surfaces of silver. The discs have cooling fins of sheet metal, preferably copper. The number of gaps in circuit may be varied by suitable switch apparatus.

For further particulars of the invention, see British Patent No. 122640.

407. ARC OSCILLATION GENERATORS. H. C. Rentschler. (*British Patent* 135185, November 10th, 1919, Convention date November 9th, 1918. Patent not yet accepted but open to inspection.)

The arrangement described is shown diagrammatically in Fig. 1. A containing vessel V which is mounted upon the pivoted arm A so that it can be swung into either a horizontal or a vertical position, encloses the two electrodes E_1 and E_2 and an additional mercury electrode M. To start the arc the switch S is placed in the upper contacts and the mercury splashed into contact with the electrode E_2 so that an arc is struck. On throwing over the switch to the lower contacts the arc strikes between E_1 and E_2 and sets up oscillations in the shunt circuit L C. The electrodes should be of a refractory metal such as tungsten, molybdenum, zirconium, or chromium and the anode E_1 should be larger than the cathode E_2. The vessel may be filled with hydrogen at a pressure of 40 cm. of mercury, or with helium. Oscillations of the first type are obtained so that the total current through the arc is not reversed during an oscillation.

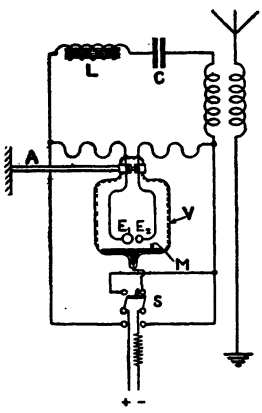

FIG. 1.

408. A SMALL POULSEN GENERATOR FOR LABORATORY MEASUREMENTS. M. Giddemeister. (*Elektrotechnische Zeitschrift*, 40, pp. 616—617, November 27th, 1919.)

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A very convenient and simple form requiring little attention burning vertically in a glass cylinder dipping into a vessel containing oil, up a tube in the centre of which passes the rod carrying the carbon electrode. The water-cooled copper electrode is carried from a metal plate which screws into a ring to which the glass cylinder is cemented. The current is 2 amperes at 220 to 250 volts. The only gas which has been found satisfactory is hydrogen.

409. HIGH FREQUENCY OSCILLATION GENERATORS. V. J. F. Bouchardon. (*British Patent* 135464, September 11th, 1919. Convention date November 21st, 1918. Not yet accepted but open to inspection.)

An arrangement of valve oscillation generators is described fed from a polyphase alternator as indicated in Fig. 2. The same alternator may be

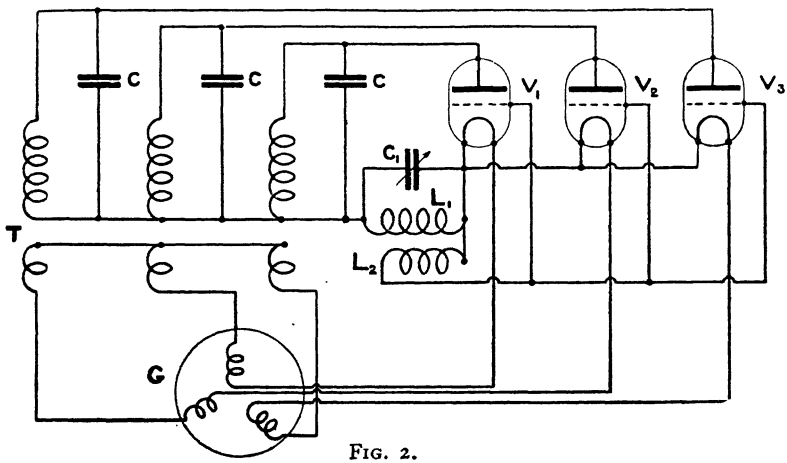

FIG. 2.

employed for feeding a polyphase spark transmitter. T is the three-phase step-up transformer, and $L_1 L_2$ the high frequency reaction coupling.*

410. HIGH FREQUENCY ALTERNATOR. O. Billieux. (*French Patent* 498164, November 22nd, 1917. Published December 31st, 1919.)

This specification describes a high frequency alternator in which the rotor consists of two discs, having teeth on their periphery and rotated in opposite directions. For this purpose they are each mounted on the end of a motor shaft. The stator consists of two armatures disposed perpendicularly to the moving discs and one on each side of the pair. A coil produces a magnetic field which traverses axially the two armatures, the two discs and the air gaps and the yoke. The discs have teeth of the same size but one has a greater number than the other.

* See also RADIO REVIEW Abstract No. 107.

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411. TRANSMITTING SYSTEMS. A. Taylor. (*French Patent* 498367, April 15th, 1919. Published January 9th, 1920.)

The specification describes improvements in radio-telegraphic transmission systems.

For further particulars, see British Patent 133901.*

412. TELEPHONE REPEATERS. B. Gherardi and F. B. Jewett. (*Proceedings American Institute of Electrical Engineers*, 38, pp. 1255—1313, November, 1919.)

A history of the development of telephone repeaters is given including descriptions of various methods of using three-electrode valves for this purpose.

413. RADIOTELEPHONY. E. B. Craft and E. H. Colpitts. (*L'Elettrotecnica*, 6, pp. 731—734, November, 1919, Abstract.)

The full paper is given in *Proceedings of the American Institute of Electrical Engineers*, 28, p. 337, March, 1919.

414. THE USE OF WIRELESS TELEPHONY FOR AIDING THE OPERATION OF AN ELECTRIC POWER DISTRIBUTION COMPANY. (*Electrical Review, Chicago*, 75, p. 668, October 18th, 1919.)

Refers to the decision of the Georgia Railway and Power Company, to install wireless telephone apparatus at their central and sub-stations, and at various points along their high-tension lines.

415. WIRELESS TELEPHONY. N. H. Slaughter. (*Journal of the Franklin Institute*, 189, pp. 1—24, January, 1920. *Telegraph and Telephone Age*, 37, p. 580, November, 1919, Abstract.)

The paper deals mainly with the development of wireless telephone sets for use in U.S. aircraft during the latter stages of the war. Prior to the beginning of the European War, wireless telephony had been used in military operations to a negligible extent, but almost immediately following the declaration of war by the United States orders were issued for the development of an aeroplane wireless telephone set. This development was undertaken by the Western Electric Company and the instruments described and illustrated in the paper are those manufactured by this company. The power plant comprises a wind driven generator yielding 25 and 275 volts for the filament and anode circuits respectively, and provided with a differential field winding connected in series with a two-electrode regulating tube so that a practically constant output voltage is obtained for all speeds between 4,000 and 12,000 r.p.m. A schematic diagram of the connections of the complete installation is given in Fig. 3, and shows both the transmitting and receiving circuits. The method of modulation used in the transmitter is the "constant-current" method. The choking coil L_0 maintains the

* RADIO REVIEW Abstract No. 218.

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output current from the generator practically constant, so that when a varying current is drawn by the plate circuit of the modulator tube, under the influence of the transmitting microphone, this varying current is diverted from the anode circuit of the oscillating valve, thus controlling its output. A special sound insulating helmet was developed which almost completely excluded

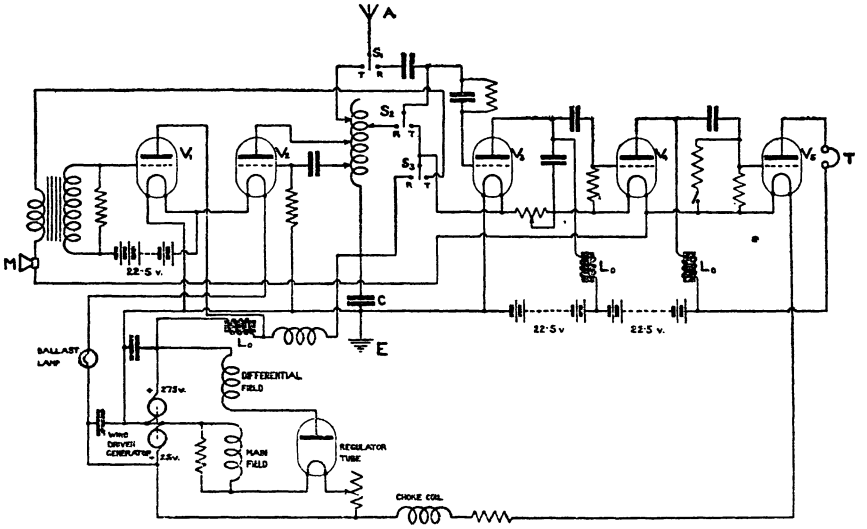

FIG. 3.

all sounds from the aviator's ears other than those received in the telephones. A single wire aerial was used of about 200 feet in length. A special form of reel for holding this wire was developed and was fitted with a centrifugal governor so as to limit the speed at which the wire is unreeled, thus preventing the breaking of the wire when the end is reached. A later type of apparatus is also illustrated in the paper but is not described in detail.

416. DEPENDENCE OF THE INPUT IMPEDANCE OF A THREE-ELECTRODE VACUUM TUBE UPON THE LOAD IN THE PLATE CIRCUIT. J. M. Miller. (*Bulletin of the Bureau of Standards*, 15, pp. 367—385. *Bureau of Standards Scientific Paper*, No. 351, November 21st, 1919.)

When used as an amplifier with the grid so negative that no electrons pass to it from the other electrodes, the input circuit is coupled with the output circuit through the internal capacities of the tube. The calculated formulæ based on these capacities are checked by actually measuring the various internal capacities of several tubes and then measuring the apparent resistance and capacity of the input circuit for various types of load in the anode circuit. Observed and calculated values are found to agree. With resistance or capacity loads the input circuit has always a positive resistance, but with

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inductive loads the input circuit may have a negative resistance, thus leading to increased amplification and sustained oscillations. Detailed calculations are given in the paper.

417. THE VACUUM-TUBE AS A GENERATOR OF ALTERNATING-CURRENT POWER. J. H. Morecroft and H. T. Friis. (*Proceedings American Institute of Electrical Engineers*, 38, pp. 1193—1221, October, 1919.)

A "P—10" type "pliotron" tube was used for these tests. Rated anode voltage = 1,000—2,000 volts, filament current 3·65 amps., and safe loss on plate 250 watts. The first part of the paper deals with the operation of the tube when separately excited with an alternating p.d. superimposed upon the steady voltage in the grid circuit, and gives an account of an oscillographic study of the waveforms and phase relations of the grid and anode voltages and anode current. A load circuit consisting of a resistance (variable) in series with a condenser was joined across the tube to absorb the A.C. power output. It was found that the output reached a maximum for some particular value of the load resistance, and increased with the square of the exciting A.C. voltage in the grid circuit up to a certain value of that voltage, and afterwards more slowly.

With a properly evacuated tube the amount of power that can be expended on the plate is sufficient to bring it to a dull red heat. If the values of the applied voltages are properly adjusted, the power output in the load circuit may be greater than that used on the plate, and the safe value of the D.C. anode circuit input may be as much as three times the safe plate rating. The usual working efficiency of the tubes is about 30 per cent., but it has been found possible to obtain over 70 per cent. efficiency by proper adjustments,* although on the assumption of sinusoidal currents the output cannot be greater than half the input.

Tests indicated that a direct current ammeter used to measure the filament current does not indicate that current correctly when the tube is oscillating, and that the filament temperature is much hotter when oscillating than when not oscillating. The ordinary static characteristics do not give a true criterion as to the operation of the tube when oscillating as the grid and plate get hotter when taking the static curves than they do in normal operation under the same conditions.

Calculations indicated that both the losses and output of the tube are greatest for a sinusoidal plate current, but that the efficiency is then low. As the plate current is made to approach the form of a short pulse the efficiency rises, and for such a short pulse with a rectangular waveform the efficiency may reach 82 per cent. To obtain high efficiency the conditions should be so adjusted that during this short pulse, which occurs when the plate voltage is a minimum, the saturation current should flow.

A few tests were also made with the tube self excited, but difficulties were experienced in obtaining the high efficiencies owing to the alternating com-

* Neglecting the filament power input.

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ponents of the plate and grid voltages not being exactly 180° out of phase, and a special means of adjusting this phase is suggested. Some experiments were also made with high-frequency self-excited oscillations, and these substantially confirmed the low-frequency tests.

418. THE AMPLITUDE OF THE OSCILLATING CURRENT SET UP BY AUDION GENERATORS. A. Blondel. (*Comptes Rendus*, 169, pp. 943—948, November 24th, 1919.)

This paper continues the treatment given in an earlier communication * dealing with the derivation of the oscillation characteristics of triode valves by a graphical construction from a family of static curves. It deals particularly with the first case there considered, viz., the use of an inductive reaction coupling between the anode and grid circuits of the valve, and an example is given of the derived characteristics, showing the method of construction, for one such case. The bulk of the article is devoted to a mathematical treatment prepared to show that the amplitude of the oscillations is zero when the conditions of priming are strictly realised (decrement reduced to zero by retroaction), and how the amplitude of the oscillations is limited by the curvature of the static characteristic starting with the simple fundamental equations of the anode circuit (consisting of inductance and capacity branches in parallel) equations are deduced for ω ($= 2\pi \times$ frequency), and for the amplitude of the fundamental of the current. These equations involve the constants of the circuit and the slopes of the oscillation characteristics.

419. CONTRIBUTION TO THE THEORY OF AUDION GENERATORS: THE CONDITION FOR EXCITATION AND THE DEGREE OF DAMPING OF FEEBLE OSCILLATIONS OBTAINED FROM THIS APPARATUS. A. Blondel and C. Lavonchy. (*Revue Générale de l'Électricité*, 6, pp. 875—893, 923—930, December 20th and 27th, 1919.)

This article is based upon a previous publication by A. Blondel † dealing with the conditions for the excitation of oscillations in triodes.

The present article is almost entirely mathematical, and deals first with the theory of sustained oscillations making use especially of a general mathematical theorem due to Hurwitz. In particular the treatment centres round the condition at the limit of self-excitation, *i.e.*, round the point at which the damping has been reduced to zero (by the retroactive coupling), and the transition period has been reached between stability and the instability when sustained oscillations are set up. Three oscillatory states are defined—below, at, and above this transition point—and a series of equations is evolved relating to these states.

The second section of the paper gives the application of the theory to a study of the sustained oscillations set up by a triode. The cases considered

* RADIO REVIEW Abstract No. 352.

† *Journal de Physique*, July, 1919.

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include a " flywheel " coupling between the anode and grid circuits ; a tuned anode coupled to an untuned grid circuit ; an aperiodic state obtained with the grid and anode circuits inductively coupled but with neither circuit oscillatory ; and a general case with tuned anode circuit coupled inductively to the grid, and with an additional capacity coupling between the anode and grid of the valve.

The third section of the paper deals with the stability of the amplitude of the sustained oscillations. The treatment is based upon the special plate-current—plate-voltage characteristics previously described by A. Blondel,* and the influence of the curvature of the characteristics upon the stability is shown. The dynamic characteristic of the lamp, whether a straight line or an ellipse, ends in the regions of the derived characteristics where the effective resistance (slope of the characteristic) is sufficient to limit any further increase of amplitude by reason of the damping to which it gives rise. The mathematical treatment should be referred to in the original.

420. DETERMINATION OF THE OUTPUT CHARACTERISTICS OF ELECTRON TUBE GENERATORS. L. M. Hull. (*Bulletin of Bureau of Standards*, 15, pp. 497—517. *Scientific Papers of the Bureau of Standards*, No. 355, December, 1919.)

The direct coupled circuit is taken in this paper as typical of the circuits which may be used with triode valves for the purpose of generating oscillations. In this circuit the anode is joined to the grid through an inductance across which is shunted the condenser, the filament being joined to a tapping on the inductance. A portion of the inductance is thus included in the anode circuit and a portion in the grid circuit. The capacity (in series with a resistance) shunted across the whole inductance represents the antenna. The paper is divided into five sections, namely, introduction, oscillating tube, derived characteristic, power output, current output. The fundamental component of the electron current which will be supplied by a given tube, under the action of sinusoidal plate and grid voltages can be computed as functions of these voltages from a family of " static characteristics " of the tube. Curves showing the plate and grid currents as explicit functions of the grid voltage, taking account of the simultaneous changes in plate voltage which would occur if these currents supplied an output circuit having a given ratio of coupling reactance, are called the derived characteristics of the tube. The effective power output of the tube is :

$$P_0 = \frac{nE_g}{2}\left(I_p - \frac{1}{n}I_g\right)$$

where E_g is the amplitude of the grid voltage, I_p and I_g are the amplitudes of the fundamentals of the plate and grid currents respectively, and n is the ratio of the plate and grid coupling reactances. Hence the efficiency of the tube for any inductively coupled output circuit is :

$$\eta = 0{\cdot}5\frac{E_g}{E_0}\left(\frac{nI_p - I_g}{{}_0I_p}\right)$$

* RADIO REVIEW Abstract No. 352.

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Where E_0 is the steady supply voltage and ${}_0I_p$ is the reading of the direct current ammeter in the other circuit. It is possible to get 50 per cent. efficiency from a tube if n is chosen so that

$$(I_p - I_g/n) = {}_0I_p \text{ when } E_g = E_0/n.$$

Physically this implies that the fundamental constituent of the plate current must be greater than the direct current constituent by the amount I_g/n, that is the plate current wave must be flattened at both extremes of the alternation. It is a familiar experimental fact that a highly distorted or flattened wave of the plate current leads to high efficiency, though not necessarily to high output.

From the current characteristics of the tube the power output can be obtained graphically as a function of the grid voltage: $P_0 = f(E_g)$.

Moreover
$$E_g = L_g\sqrt{\frac{P_0}{RCL}}$$

where L_g is the grid inductance and R, C, and L, are the total resistance, capacity and inductance respectively of the antenna circuit. A simultaneous graphical solution of these two equations gives the power output from the tube as a function of any of the three electrical constants of the output circuit. Such solutions can be obtained graphically for any type of tube whose static characteristics are known. A number of curves are given in the paper illustrating these graphical solutions and the various output currents and harmonic constituents of the output currents obtainable from various tubes.

421. THE ALGEBRA OF IONIC VALVES. W. H. Eccles. (*Electrician*, 84, pp. 162—163, February 13th, 1920.)

This paper is written as an introduction to the theory of ionic tubes, and deals first with diodes, and then with triodes.

Considering only the straight part of the characteristic curve, its equation may be written

$$i_a = h_a(e_a - e_s),$$

where i_a is the anode current, e_a the anode voltage, h_a the slope of the characteristic line, and e_s the intercept on the e_a axis when the straight part of the characteristic is produced. This quantity e_s may be regarded as a back E.M.F. in the tube. Under these conditions the tube may be said to obey Ohm's law. If h_a and e_s are given their appropriate values corresponding to the point considered, the same equation may be used to represent the conditions at that point.

In the case of triodes, using the same reasoning, the above equation becomes:

$$i_a = h_a(e_a + ge_g - e_s),$$

where g is the voltage factor, and e_g is the grid voltage. Writing this equation as

$$i_a = h_a e_a + h_g e_g + h_o$$

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the first equation suggested by Latour is obtained.* The symbol e_l may be used for $e_a + ge_g$ and is called the lumped voltage. Applying the above to the case of a triode amplifier, with a resistance R in the anode circuit, and writing r_a for $1/h_a$, the internal resistance of the tube, the expression for the voltage amplification becomes $\frac{Rh_g}{1 + Rh_a}$ or $\frac{gR}{R + r_a}$. This result is correct for both the curved and straight parts of the characteristic.

422. A GRAPHICAL STUDY OF THE OPERATION OF AUDIONS AS SENSITIVE RECEIVERS OR AS DECREMENT REDUCERS ("*desamortisseurs*") IN A RESONANT CIRCUIT. A. Blondel. (*Comptes Rendus*, 169, pp. 1377—1382, December 29th, 1919.)

The continuation of a previous paper † dealing with the derived characteristics of triode valves. When these characteristics are plotted in terms of i (the variable part of the plate current) instead of e (the variable part of the plate voltage) they enable the amplifying properties of these valves to be studied when the coupling is adjusted below the value necessary to sustain oscillations, and when a forced oscillation of the resonant frequency is applied to the apparatus. Two cases are considered, (1) when the alternating E.M.F. is applied to the plate circuit, and (2) when it is applied to the grid, and it is shown how, by means of the curves given, the amplitude of the resultant oscillatory current in the plate circuit may be obtained graphically in each case.

423. THE CALCULATION OF AUDION CONSTANTS. R. W. King. (*Physical Review*, 14, pp. 532—533, December, 1919. Abstract of Paper read before the American Physical Society.)

Given the characteristic equation of a triode as $I_p = \kappa \left(\frac{E_p}{\mu} + E_c\right)^{\eta}$ it has been found possible to deduce expressions for μ and κ from theoretical considerations.

Let α = distance from plate to grid (flat plate).
β = " " grid to filament (flat plate).
n = number of grid wires per unit length.
r = radius of the grid wires.
A = total plate area.
R_p = radius of cylindrical plate.
R_g = " " grid.
R_f = " " filament.
l = length of the complete cylindrical structure.

The following results were obtained, assuming $\eta = \frac{3}{2}$:—

* M. Latour, *Electrician*, 78, pp. 280—282, December 1st, 1916.
† RADIO REVIEW Abstract No. 418.

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(1) Flat plate type with the filament symmetrically placed between grids and plates:

$$\mu = \frac{2\pi rn}{\log_\epsilon (1/2\pi\alpha n)}$$

$$\kappa = 2{\cdot}33 \times 10^{-6} \frac{A}{\sqrt{\alpha+\beta}} \left(\frac{\mu}{\alpha+(\mu-1)}\right)^{\frac{3}{2}}$$

(2) Cylindrical type with coaxial single strand filament:

$$\mu = \frac{\left(2\pi R_g^2 \frac{1}{R_g} - \frac{1}{R_f}\right) n}{\log_\epsilon \frac{1}{2\pi rn}}$$

$$\kappa = 14{\cdot}65 \times 10^{-6} \frac{l R_p^{\frac{1}{2}} \mu}{[(R_p - R_g) + R_g(\mu+1)]^{\frac{1}{2}}}$$

(3) Cylindrical type with several parallel strands of filament arranged on an internal or external coaxial cylinder:

The expression for μ is the same as in case (2),

$$\kappa = 14{\cdot}65 \times 10^{-6} \frac{R_p l \mu^{\frac{3}{2}}}{\sqrt{\pm (R_p - R_f) \pm (R_p - R_g) \pm (R_g - R_f)(\mu+1)^{\frac{3}{2}}}}$$

(the signs should be chosen to make all terms positive). Some examples of measurements on type (1) valves are given in the paper, and show good agreements between the calculated and observed values.

424. THE USE OF AUDIONS OR THREE-ELECTRODE LAMPS DURING THE WAR. G. Ferrié. (*Revue Générale de l'Électricité*, 6, pp. 933—935, December 27th, 1919.)

The author refers to an article by L. Kühn published in September, 1919,* in which reference was made to the lack of development of valve apparatus in Germany. It is stated that at the time of the armistice the Germans had no valve transmitters in use. A tribute is paid to the development work carried out in America and England, and the remainder of the article is devoted to a brief summary of the various development works carried out by the French Radiotélégraphie militaire. The following are dealt with in turn: Three-electrode valves, amplifiers, valve transmitters, aircraft receivers, single-frame radiogoniometers, earth telegraphy, measuring apparatus (wavemeter standardisation), and high power stations. Dates are given indicating the historical development of these various branches.

425. AN INVESTIGATION OF THE INTERNAL ACTION OF A TRIODE VALVE. W. H. Eccles. (*Radio Review*, 1, pp. 11—20; 67—77; 127—134, 1919.)

* *Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 395—495, September, 1919. RADIO REVIEW Abstract No. 295.

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426. THE DEPENDENCE OF THE AMPLIFICATION CONSTANT AND INTERNAL PLATE CIRCUIT RESISTANCE OF A THREE-ELECTRODE VACUUM TUBE UPON THE STRUCTURAL DIMENSIONS. J. M. Miller. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 64—73, February, 1920.)

The formulæ for the relations between the anode current per unit area of filament i_a, anode voltage v_a and grid voltage v_g of a triode can be deduced theoretically from the results of Maxwell's investigation of the screening effect of a grating of equally spaced parallel wires between two infinite conducting planes. A simple application of Maxwell's formula gives the following expressions for the anode current and the internal anode circuit resistance R for a tube with plane electrodes.

$$i_a = \frac{2{\cdot}33 \times 10^{-6}}{x^{\frac{1}{2}}\left(x + \frac{b_1 b_2}{\alpha}\right)^{\frac{1}{2}}}\left(v_a + \frac{b_2}{\alpha} v_g\right)^{\frac{3}{2}} \text{amperes.}$$

$$R = \frac{x^{\frac{1}{2}}\left(x + \frac{b_1 b_2}{\alpha}\right)^{\frac{1}{2}}}{1{\cdot}8\, L} \frac{10^6}{\left(v_a + \frac{b_2}{\alpha} v_g\right)^{\frac{1}{2}}} \text{ ohms.}$$

where b_1 = distance filament to grid.
b_2 = distance grid to plate.
$x = b_1 + b_2$.
$\alpha = -\frac{a}{2\pi}\log_\epsilon\left(2 \sin\frac{\pi c}{a}\right)$
c = radius of grid wire.
a = distance between grid wires.
and L = length of filament.

Using these formulæ satisfactory agreement is found between measured and computed values in the case of tubes having plane grids and anodes, but not for tubes of cylindrical design. Curves are given for the rapid pre-determination of amplification constants from structural dimensions.

427. IONIC OSCILLATIONS IN THREE-ELECTRODE THERMIONIC VALVES. R. Whiddington. (*Radio Review*, 1, pp. 53—58, November, 1919.)

428. PRODUCTION OF VACUUM TUBES FOR MILITARY PURPOSES. N. H. Slaughter. (*Physical Review*, 14, pp. 453—456, November, 1919.)

The specification, production, testing and performance of the vacuum tubes manufactured for use by the U.S. Signal Corps during the war are dealt with in this paper.

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429. RECEIVING APPARATUS. E. Bellini. (*French Patent* 497848, April 5th, 1919. Published December 18th, 1919.)

The invention consists in a receiving arrangement for directive wireless telegraphy and telephony, and it has for its object to render very distinct the direction of the maximum intensity of reception. The invention is characterised by the employment of an auxiliary circuit which may be oscillating or not, coupled to two aerials or two radiogoniometer secondary circuits, which are untuned. The aerials or the said circuits when not directed towards the transmitting station will produce an electromotive force and a current in the auxiliary circuit, and by adjusting the radiogoniometer coils until no current is produced in the auxiliary circuit the direction of the received signals is ascertained. Various arrangements of auxiliary circuits are illustrated.

430. VARIATION IN DIRECTION OF PROPAGATION OF LONG ELECTROMAGNETIC WAVES. A. H. Taylor. (*Bulletin of Bureau of Standards*, 15, pp. 419—433. *Bureau of Standards Scientific Paper*, No. 353, November 29th, 1919.)

Describes a method of getting absolute zero with a direction finder by compensating the antenna effect by means of mutual inductance from a coil supplied from another frame aerial at right angles to the main coil. The two-coil (Robinson) method is compared with the single-coil minimum method and found to give equally good results, although it is stated that the former requires more experience. The apparent bearings of Annapolis 35 miles and New Brunswick 175 miles away have been studied and tables and curves are given showing the variation. In one case at sunset, New Brunswick appeared to shift 68° in sixteen minutes. Tests on 4,000 metre waves show smaller variation than the long waves. Tests on still shorter waves are in progress. Spark signals appear to show smaller variations than continuous wave signals. The reasons are briefly discussed, and it is suggested as probably being due to less well defined interference effects, between waves travelling between the stations by different paths, with damped wave trains than with continuous waves. Hence the former would show smaller apparent variations.

431. THE FESSENDEN PELORUS (WIRELESS COMPASS): A CAUTION AS TO ITS USE. R. A. Fessenden. (*Electrician*, 83, pp. 719—721, December 19th, 1919. *Revue Générale de l'Électricité* 7, p. 85D, March 13th, 1920, Abstract. *L'Électricité* 2, p. 16, March 15th, 1920, Abstract. *L'Elettrotecnica*, 7, p. 103, February 25th, 1920.)

A brief description is given of the various types of the Fessenden "Pelorus," including many references to the original descriptions and patent specifications. Errors in the readings may be due to: opaque regions due to varying local conductivity of the ground; varying local and temporal absorption due to vegetation; the difference between the resistance of water and of a sandy beach. The last causes the waves to bend in towards the land. In the latest

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type of " Pelorus " readings are taken on two or more wavelengths, as it has been found that the amount of directional error is a function of the wavelength. Hence when a difference is noted between the apparent directions measured on different wavelengths, it indicates that some error is present, and by observations of the differences between the different wavelength readings, it has been found possible to estimate the magnitude of the error and allow for it. The paper includes a curve taken by the U.S. Navy Department showing the variations in apparent direction through a week. The errors were greatest during the night and generally towards the shore side, but occasionally errors in the other direction were noted due apparently to clouds of ionised air.

432. DIRECTIONAL SYSTEMS OF WIRELESS TELEGRAPHY. (*Génie Civil*, 75, p. 671, December 27th, 1919.)

Abstract of lecture by H. R. Sankey—see RADIO REVIEW Abstract No. 147 for the original.

433. PROPAGATION OF ELECTROMAGNETIC WAVES OVER A PLANE CONDUCTING SURFACE. H. Weyl. (*Annalen der Physik*, 60, pp. 481—500, November 20th, 1919.)

A mathematical paper, the physical results of which are not clearly stated. The author criticises adversely the method adopted by Sommerfeld but also obtains a result which may be regarded as a superposition of a space wave and a surface wave.

434. A SYSTEM FOR THE RECEPTION OF CONTINUOUS WAVES. J. Scott-Taggart. (*Wireless World*, 7, pp. 593—601, January, 1920. *Electrical Review*, 85, pp. 808—809, December, 1919, Abstract.)

Paper read before the Wireless Society of London. For abstract see RADIO REVIEW, 1, pp. 181—183, January, 1920.

435. WHY TICKLER COILS ARE INEFFICIENT FOR LONG UNDAMPED WAVES. (*Everyday Engineering Magazine*, 8, p. 104, November, 1919.)

Resonance curves are given showing the loss of energy at the receiver brought about by the detuning necessary to obtain an audible heterodyne note at long wavelengths. The use of a separate heterodyne is advocated for long wavelengths in order to reduce this loss.

436. RECORDER. L. Williams. (*French Patent* 497912, April 7th, 1919. Published December 20th, 1919.)

The invention consists of an electrically operated recording or reproducing instrument which may be employed for producing a record of the number and character of electric waves produced in wireless telegraphy. The marking fluid is contained in a well having a fine outlet into which an electrode dips, and the arrangement is such that when current flows between the

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electrode and the well, the fluid is expelled and thus indicates the passage of the current by the mark on a recording strip.

For further particulars of this invention, see British Patent No. 123220.

437. THE PHOTOGRAPHIC RECORDING OF WIRELESS MESSAGES. (*Génie Civil*, 75, p. 387, October, 1919.)

Describes apparatus developed by the General Electric Company (U.S.A.).

438. THE USE OF THE THREE-ELECTRODE VALVE AS A RELAY. W. H. Eccles and F. W. Jordan. (*Revue Générale de l'Électricité*, 6, p. 812, December, 1919. *L'Elettrotecnica*, 7, p. 82, February 15th, 1920. *Radio Amateur News*, 1, p. 349, January, 1920, Abstract.)

Abstract of paper read before the British Association (see RADIO REVIEW, 1, pp. 143—146, December, 1919).

439. RECORDING OSCILLOGRAPHS AND AMPLIFIERS OF EXTREMELY LOW FREQUENCY; THEIR APPLICATION TO THE RECORDING OF RADIOTELEGRAPHIC SIGNALS. H. Abraham and E. Bloch. (*Revue Générale de l'Électricité*, 7, pp. 211—222; pp. 255—272, February 14th and 21st, 1920.)

Reviews critically all the methods previously used for the automatic registration of wireless signals and describes successful experiments made in 1916–18 for the French Army with valve amplifiers and Morse and other recording apparatus. The latter require working currents of the order of one milliampere and to reach this value the valve amplification must be pushed to a maximum. This has been done by a combination of H.F. and L.F. amplifiers, the resultant Morse signals being amplified by special instruments designed for extremely low frequencies so that the rhythm of the signals can be followed.

For reception a coil was used in place of an ordinary antenna because it was found possible to eliminate the effects of strays more completely by taking advantage of the radiogoniometric properties of the former. Most of the work was done with a circular coil 1·2 metres in diameter, and having 40 turns 14 mm. apart.

The two French military amplifiers types R_1 and R_6 are described. The type R_1 is a nine valve arrangement, resistance coupled, and can be used as an autodyne receiver. The type R_6 is an eight valve amplifier of superior design with both resistance and capacity coupling. Its special features are (*a*) the arrangement of connecting leads inside the amplifier case, and (*b*) the high resistance pancake coils which are included in the anode circuits and prevent instability. This instrument is designed to give maximum amplification on wavelength between 3,000 and 6,000 metres. A separate heterodyne must be used with it.

Two other novel types of amplifiers have been devised—one for extremely low frequencies and one for continuous currents. In the first type the connections between successive valves are made by means of condensers of 0·1 or 0·2 mfd. capacity. Each condenser is thus included in a high resistance cir-

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cuit of several megohms and thus possesses a time constant which may be as large as several seconds. Hence, oscillations, the period of which is less than this amount will be efficiently amplified by this arrangement. In all cases the linking condensers are made as small as the rhythm of the signal currents will allow. For example, for the reception of signals sent by hand 0·5 mfd. is used; in the case of automatically sent signals of 40 or 50 words a minute 0·1 mfd. is sufficient. Experience shows that it is a good plan to shunt the anode circuit resistance (60,000 ohms) with capacities of the order of 0·25 mfd. in order to prevent reaction between this amplifier and the ordinary audio-frequency amplifier which precedes it in the stages of amplification.

The second type—the continuous current amplifier—will function at all frequencies. It is of the resistance coupled type but a battery is included in the wire connecting the high resistance in the anode circuit of one valve to the grid of the next so that the grid potential may be maintained at its most favourable value.

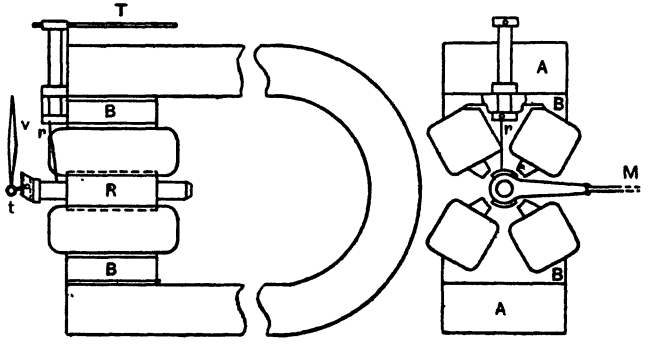

FIG. 4.

The recording apparatus used was specially designed for the work, and was of the moving iron type as it was not possible to get a moving coil instrument of sufficiently short period to respond with a milliwatt. The principle on which the recorder works is similar to that of a quadrant electrometer except that its action is magnetic instead of electric. A diagram of the essential parts is shown in Fig. 4, where A is a permanent magnet which has for its pole pieces the cores of two electromagnets BB, each with two coils arranged so that the magnetic force is radial. A rotor R of iron is placed along the axis. Its form is such that it is nearly in indifferent equilibrium between the poles. A spring of variable tension gives it a position of stable equilibrium. The connections between the four coils are made in such a way that the passage of the current which augments the field due to one pole diminishes that due to the two adjacent poles and augments the one opposite. The rotor thus tends to turn in the direction of the stronger field. The moving iron cannot carry the pen (which produces a trace on smoked paper) directly, but causes the trace with the aid of an intermediary lever.

Most of the large European stations have been recorded using the amplifying assembly and this recorder (examples of Morse and oscillograph types are

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given), no trouble with atmospherics being experienced. For the American stations regenerative circuits and very sharp tuning are necessary. The amplification is made so enormous that the anode current of the last valve reaches saturation value during a signal. This current is not altered by any strays however strong the latter might be. During the intervals between the signals the grid of the last valve becomes strongly negative and a stray of moderate intensity has not sufficient effect to cause this potential to mount to zero. Moreover, in the case of two sets of signals simultaneously heard on a telephone set, but sufficiently unequal in intensity, the record of the stronger signals only is obtained on the oscillograph.

440. "RECEPTION THROUGH STATIC AND INTERFERENCE," BY R. A. WEAGANT. L. de Forest. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 543—553, October, 1919.)

A critical discussion (mainly adverse) by Lee de Forest of the above paper.* Weagant's reply is included.

441. MY INVENTIONS (VI.). N. Tesla. (*Electrical Experimenter*, 7, p. 506, October, 1919.)

This instalment contains a criticism of Weagant's claims in respect to his X-stopper.* Tesla states that artificial and natural ætheric disturbances are propagated in exactly the same way, both setting up electromotive forces in a horizontal as well as in a vertical sense.

442. THE UNI-CONTROL RECEIVER. R. E. Thompson. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 499—516, October, 1919.)

Proposes a design for a receiver which will provide a gradual and continuous sweep from the shortest to the longest wavelengths within the range of the instrument. A set of capacity and inductance switches are geared together and controlled by a single handle to provide continuous variation of circuit frequency. The use of a motor for turning this handle is proposed. To prevent the continual jamming produced by ship-to-shore and ship-to-ship communication on one wavelength, it is proposed that ships should use different wavelengths and be fitted with a uni-control receiver.

443. STANDARDISATION OF RECEIVER WAVELENGTH RANGES. (*Everyday Engineering Magazine*, 8, p. 116, November, 1919.)

A plea for the more accurate definition of the wavelength ranges of receiving apparatus. Five classes of receivers are suggested for wavelength ranges between 60 and 20,000 metres.

444. THE HOROPHONE. (*Electrical Review*, 85, p. 767, December, 1919.)

A description is given of a compact receiving set specially designed for receiving time signals sent from the Eiffel Tower radio station.

* See RADIO REVIEW Abstract No. 18.

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445. THE UNITED STATES NAVAL COMMUNICATION SERVICE. S. W. Bryant. (*Journal of the Franklin Institute*, 188, pp. 751—770, December, 1919. *Technical Review*, 6, p. 226, March 2nd, 1920.)

The U.S. Naval Radio Service was established in 1912. Its name was subsequently altered to the "Naval Communication Service" while at the same time the scope of its activities was extended to cover both wire and cable communications as well as wireless.

This article summarises the work of this department, and deals particularly with its activities during the war, especially in connection with U.S. communications to and from Europe and in the establishment of radio-compass stations and also centralised control stations for regulating the working of groups of radio stations in congested areas.*

446. THE PROGRESS OF WIRELESS TELEGRAPHY DURING THE WAR. J. Bion. (*Technique Moderne*, 11, pp. 417—423, October, 1919.)

The rapid development of continuous wave radio work during the war seems to indicate that soon only C.W. will be employed in practical working.

The improvements made in the three-electrode valve have enabled it to be used as an ultra-sensitive detector and amplifier, and have also enabled great strides to be made in low power radiotelephonic work. Wireless direction finding has also been developed and considerable accuracy is now obtainable.

447. THE WIRELESS TELEGRAPH APPARATUS OF THE GERMAN ARMY. A. Salomon. (*Revue Générale de l'Électricité*, 6, pp. 833—843, December, 1919. *Electrical World*, 75, p. 909, April 17th, 1920.)

The following apparatus is described and illustrated:—

Telefunken Dynamo-Alternator, giving D.C. and 540 ~ A.C.
Telefunken and Bosch Alternators for Aircraft, etc.
Pedal and Handcrank Driving Apparatus for Generators.
Deutsche Telephonwerke combined Transmitting and Receiving Set.
Telefunken Receiving Apparatus.
Deutsche Telephonwerke Complete Receiving Set.
Two-stage and Four-stage Valve Amplifiers.
Earth Telegraphy Apparatus.

448. A NEW TRANSFORMER AND OIL CONDENSER. (*Everyday Engineering Magazine*, 8, p. 107, November, 1919.)

449. STANDARDISED AUDION CONTROL PANELS. M. B. Sleeper (*Everyday Engineering Magazine*, 8, pp. 102—103, November 1919.)

Constructional details and illustrations of panels for mounting audions o experimental purposes.

* See also RADIO REVIEW Abstract No. 360.

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450. WIRELESS IN WARTIME GERMANY. (*Scientific American*, 121, p. 575, December, 1919.)

A short note summarising some of the wartime developments in Germany. It is mentioned that the capacity of the Goldschmidt machine at Eilvese was increased to 800 kw. towards the end of the war. Methods of double sending with two transmitters acting on one antenna were also developed.

451. LONG DISTANCE RADIO COMMUNICATION IN CHILE. E. W. Fielding. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 59—63, February, 1920.)

A detailed description of the construction and working of the Chilean radio stations at Llanquihue and Punta Arenas.

452. THE SUBMARINE'S UNDER-WATER RADIO. (*Electrical Experimenter*, 7, p. 539, October, 1919.)

An account of experiments and developments due to the Bureau of Standards, leading to a system of wireless transmission and reception during submergence.*

453. A LOOP OF WIRE. W. J. Henry. (*Scientific American*, 120, p. 368, October, 1919.)

A popular account of the use of loop aerials in trench wireless sets.

454. HOT-WIRE TELEPHONES. A. Williams and L. D. Williams. (*British Patent* 131258, May, 1919. Patent accepted, August 21st, 1919.)

Describes various arrangements of metal-foil heaters for thermal telephones.

455. IMPROVEMENTS IN INDUCTANCE COILS. H. A. Ewen. (*British Patent* 133513, November, 1918. Patent accepted, October 16th, 1919.)

The special feature claimed in this patent is the use of a metal strip of U-shape section which is wound up to form the inductance. The edges of the strip may be embedded wholly or partly in an insulated material to provide mechanical support, and connection is made to any point of the strip by means of a plug fitting between the adjacent sides of the U.

456. "THE ELECTRICAL OPERATION AND MECHANICAL DESIGN OF AN IMPULSE EXCITATION MULTI-SPARK GROUP RADIO TRANSMITTER," BY B. WASHINGTON. E. W. Stone. (*Proceedings of the Institute of Radio Engineers*, 7, pp. 541—542, October, 1919.)

A further discussion of the paper with the above title.†

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* See also RADIO REVIEW Abstract No. 85.

† See also RADIO REVIEW Abstract No. 8.

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457. ELECTRIC CONDENSERS. W. H. Edridge and E. E. G. Boite. (*British Patent* 130667, March 8th, 1918. Patent accepted, August 14th, 1919.)

The arrangement described provides for fine adjustment of the capacity of variable condensers of the vane type by means of a worm wheel mounted upon the spindle of the condenser. An auxiliary handle serves to turn the worm through a friction drive. Means is provided for disengaging the worm and wheel when desired.

458. CONDENSERS. W. H. Edridge and E. E. G. Boite. (*French Patent* 497970, March 8th, 1919. Published December 23rd, 1919.)

This specification describes variable condensers for wireless telegraphy and telephony.

For further particulars, see British Patent No. 130667.*

459. TELEMECHANICAL COMMUTATOR. R. Martin. (*French Patent* 693368, April 20th, 1916. Published August 7th, 1919. *Revue Générale de l'Électricité*, 7, p. 118D, April 10th, 1920, Abstract.)

Arrangements are described for the control of any form of distant apparatus by wireless. A special form of relay is employed.

460. ELECTRIC RESISTANCES, SENSITIVE TO LIGHT. T. W. Case. (*British Patents* 133403 and 133404, September, 1918. Patents accepted, October 10th, 1919.)

A compound comprising thallium and sulphur, preferably thallium-oxy-sulphide, is described for use in a photophone receiver. The second patent deals with constructional details and with the mounting of the sensitive material.

461. NAVAL AIRCRAFT RADIO. T. Johnson, Jr. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 3—58, February, 1920.)

Experiments on the use of wireless by naval aircraft have been carried out by the United States Navy Department from 1912 onwards. The results of early work are summarised and the modern standard transmitting telegraph and telephone sets described. Of the spark transmitters now in use two are of the same design—synchronous rotary spark. These sets are mounted in a stream line case on the wing of the flying boat, the generator and spark gap being driven by a small propeller. Wavelengths from 200 to 500 metres are available in one set and from 335 to 425 metres in the other. Another standard transmitter is of the impact excitation type (two tungsten gaps in series) designed for work on 375 metres only.

In the description of the standard service transmitting valves the question of Wehnelt coated filaments *versus* tungsten filaments is discussed, the

* RADIO REVIEW Abstract No. 457.

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evidence being in favour of the former for very low power transmitters and the latter for high power work.

For use on telephone sets a microphonic transmitter has been specially designed which is so mounted that it is exposed on both sides to extraneous noise vibrations and only affected by the directional impulses of the voice from one side. In order to prevent the carbon granule from falling away from the front electrode when the transmitter is held in a horizontal position the button is mounted at an angle of 30 degrees with the diaphragm.

To enable transmission to be carried on from the craft while resting on the

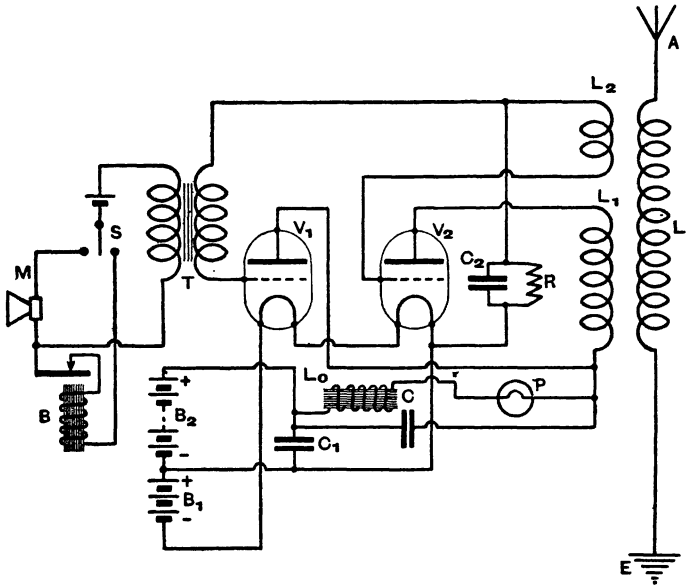

FIG. 5.

water a storage battery is used which is charged by means of a generator which is driven whenever the engine is running. The same fundamental circuit (see Fig. 5) is used for all craft and provides communication by either continuous wave telegraphy, buzzer-modulated telegraphy or telephony.

For continuous wave telegraphy the tube V_2 is used as "oscillator," the telegraph key being inserted in the grid leak R. The tube V_1 is used as a "modulator." The buzzer B and the microphone M are interchangeable by means of a switch, S. The output of the microphone transformer T is impressed on the grid of the modulator and the output of the modulator is introduced in the anode circuit of the oscillating tube through the incandescent lamp P, and the iron cored inductance L_0. The flickering of the incandescent lamp indicates the correct functioning of the modulator tube.

The method of determining airplane antenna constants, using a calibrated valve oscillator is described.

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2. Books.

TELEPHONIC TRANSMISSION, Theoretical and Applied. By J. G. Hill, Assistant Staff Engineer, General Post Office, London. (London: *Longmans, Green & Co.*, 1920. Pp. xvi. + 393. Price 21*s.* net.)

Mr. Hill's book is almost entirely concerned with the one feature of wire telephony which is absent in radio transmission. It is an exposition of the theoretical development and practical application of the laws governing the transmission of currents from sending to receiving station along the wires connecting them. Yet it should have much interest for the radio engineer from both the theoretical and the practical points of view. On the theoretical side, the problems of wire telephony involve the general case of current propagation. Resistance, leakance, inductance, capacitance, must all be taken into account. The wave forms with which the telephone engineer must deal are probably the most complex types known in alternating current engineering. The frequencies and electrical constants of the circuits lie in that medium range in which the energy stored in the magnetic and electric fields, and that dissipated in the conductor and the dielectric are of equal importance in determining the performance of the circuit.

In the commercial application of the laws of transmission, the divergencies between the techniques of the "wired" and the "wireless" branches are more marked. Yet the methods by which the results of scientific study are reduced to practical rules for ensuring, at minimum cost, proper standards of speech transmission and absence of interference in the older branch are of considerable interest to any radio engineers who are willing to let their imagination speculate upon the probable development of their own branch of the art and to consider what form the standardisation which must accompany development is likely to take. This is an interesting theme, but a review is not the place for following it up.

Previous books on Transmission have been text-books dealing chiefly with the application of mathematics to elucidate the theory of transmission in the abstract. Breisig, Kenelly, Fleming have all viewed the subject from this standpoint. Mr. Hill's book deals with the application of the theory of transmission to commercial telephone practice in the concrete. It is a manual containing all that a transmission expert has found useful or necessary in the course of a long experience, revised and condensed into just such a book as every specialist feels he would like to compile, or at least to possess, on his own subject.

The arrangement of the theoretical chapters is somewhat novel. The key to the treatment adopted is to be found principally in Appendix II., which contains an elementary mathematical derivation of the equations representing the relations between voltage and current in the steady state in an infinite uniform line. These are derived without use of differential equations, and the proofs will be appreciated by many to whom the solution of a differential equation is the product of a magician's wand, only to be accepted as solid

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fact after the unsatisfactory test of re-differentiation. The more orthodox methods are given in Appendix I. The results of Appendices I. and II. are applied in Chapter II. to the simple case of an infinite line under direct current. The rules for forming equivalent circuits are established in Appendix III., and applied to the direct current case of lines of any length with and without terminal apparatus in Chapter III. The sequence would be easier to grasp if the whole of this matter were included in the text instead of being split between text and appendix. Loaded lines and the design of artificial cables are dealt with in Chapter IV., still on a direct current basis. Chapter V. deals with the nature of alternating speech currents, leading up to the application of the previous work to the case of alternating currents in Chapter VI. Chapter VII. treats of the difficult subject of reflection and transmission losses and gains at points of change and impedance. Chapter VIII. commences the application of the theory to practical cases and deals with the constants of different telephone lines. A long chapter on British Post Office practice in loading follows. Methods of measurements on telephone lines, with many details of tests and apparatus are described in Chapter X., including a particularly interesting reed governor for controlling the speed of high frequency alternators. This and the two following chapters on the standard cable and its uses and on cost problems in telephonic transmission, are unique in the literature of telephone engineering. They show how, by reduction of complex formulæ to expressions seemingly empirical, yet well grounded, by admissible approximation, by experimental checks, by standardisation of methods and apparatus, and by the use of curves and graphical methods, the transmission expert has adapted the work of the mathematician content with the derivation of an algebraic expression for the use of the practical engineer demanding maximum efficiency at minimum cost.

The last chapter treats of the application of the thermionic amplifier to telephone circuits; as one reads it one feels that the changes in practice which must follow on the introduction of this long-sought-for speech relay, together with the use of ultra-sound frequencies referred to on p. 357, will soon call for a second edition of even so complete a book as that under review. Let us hope that by the time this happens telephone engineers will have adopted a standard nomenclature for this new branch of their art. "Lamp," "valve," "relay," "relay lamp" and "three electrode thermionic valve" are all used where "triode" would be applicable and precise. Mr. A. N. Whitehead has said (*Introduction to Mathematics*, p. 88), "The essential principle involved was quite clearly enunciated in Wonderland to Alice by Humpty Dumpty when he told her, *à propos* of his use of words, 'I pay them extra and make them mean what I like.'" But it is wasteful and confusing to "pay" several words "extra" to make them all mean the same thing. If that thing is new, it is far better to employ a new word than to make an old one work overtime.

Mr. Hill and the publishers are to be congratulated upon the care used in the preparation of the text and diagrams and on the get-up of the book. Misprints are very few and unimportant, and matter, formulæ and diagrams are clearly presented. The close spacing between lines of type is a little

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irritating, but if the object has been to reduce the size and cost of the volume, this can easily be forgiven.

The work is the first of a series of Manuals of Telegraph and Telephone Engineering prepared mainly by Post Office specialists under the editorship of Sir William Slingo. Mr. Hill has set a high standard for his colleagues: if they equal or surpass it, this series will form the most comprehensive and authoritative source of information available on Telegraph and Telephone practice.

W. H. GRINSTED.

COURS ÉLÉMENTAIRE DE TÉLÉGRAPHIE SANS FIL. By Georges Viard. (Paris: *Librairie de l'Enseignement Technique*. 1918. Pp. 303. Price 12 fr.)

This book is based upon a course of lectures given at the École Supérieure des Postes et Télégraphes. It is a simple non-mathematical account of the development and of the present state of the subject. It presupposes very little mathematical or scientific knowledge on the part of the reader. After a historical introduction, the first chapter is devoted to definitions and examples of force, work, power, conservation of energy, electric and magnetic fields, alternating currents, damped oscillations, harmonic analysis, etc. Chapters follow on the production and use of damped oscillations, coupling, quenched sparks, various charging circuits with D.C. and A.C. supply, the production of undamped waves, the nature of electromagnetic waves, radiating and absorbing circuits, detectors, the reception of continuous waves, radiotelegraphic measurements, constructional details of stations, and radiotelephony.

The book is lucidly written and well illustrated, and can be recommended to French readers requiring a comprehensive but non-mathematical description of the subject.

G. W. O. H.

Books Received.

WIRELESS TELEGRAPHY AND TELEPHONY—First Principles, Present Practice and Testing. By H. M. Dowsett, M.I.E.E. (London: *The Wireless Press, Ltd.* 1920. Pp. xxxi. 331. Price 9s. net.)

Correspondence.

SKIN EFFECT IN SQUARE WIRES.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—On page 227 of the issue of February, 1920, you refer to some mathematical work by Mr. H. W. Edwards on the skin effect of square conductors. In so far as Mr. Edwards' work has already been treated of by the writer in a paper on "Resistance and Reactance of Massed Rectangular Conductors" (see *Physical Review* for October, 1916) I am at a loss to understand the reliance placed upon the former's work.

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The chief difficulty appears to have been that Mr. Edwards assumed a form of general solution for his partial differential equation which was entirely unwarranted. The physical work on the other hand I have every reason to believe was quite admirably done.

A. PRESS.

East Pittsburg, Pa., U.S.A.,
March 30th, 1920.

[We were acquainted with the paper referred to by Mr. Press, but have taken the opportunity of looking through it again to confirm our impression that it was not quite satisfactory. On page 417 the author says that the only assumption made is that the field in the skin of the conductor has a rectangular path conforming to the contour of the conductor. On the following page, however, he seems to give up this assumption in favour of another, viz. that the current density is the same at all points of the skin. However this may be, he concludes with an example of a square conductor 5 mm. on the side, $S = 0{\cdot}25$ and a frequency of 2,000 ; he then states that $S\sqrt{f} = 3{\cdot}54$ which is an obvious error unless the frequency was 200 and not 2,000 as stated. His calculated value of R_f/R_o is 1·8. Now for a round wire of equal cross-section R_f/R_o is little greater than 1 for $f = 200$, and is only 1·23 for $f = 2{,}000$. His calculated value for the square wire is therefore so high compared with that for the round as to cast considerable doubt on the accuracy of the method. For these reasons we felt justified in omitting any reference to the paper.—EDITOR.]

EARLY DEVELOPMENTS OF THE THREE-ELECTRODE TUBE.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In the February issue of the RADIO REVIEW, p. 259, M. Marius Latour refers to his publication in 1916 of a theory of the three-electrode tube, and states that this "theory is now classical and has been reproduced and possibly developed, by different authors (Hazeltine, van der Bijl, Carson, Ballantine, etc.)."

I am not disposed to be drawn into polemical discussions on questions of priority, for obvious reasons. It will naturally not be easy to give proper credit as far as priority of developments in Europe is concerned, because there the three-electrode thermionic tube was developed by the stimulus of war exigencies, and the publication of the results was naturally withheld for military reasons. Now that the war is over we find that the British, French, Germans, and others have made valuable contributions to this art during the period of the war. As regards the elementary theory of operations of the three-electrode tube, there can be no question of priority. M. Latour's paper appeared several years after the fundamental problems connected with the operation of this type of device had all been solved in the United States, where the investigations were stimulated, not by the war, but prior to the war, by the requirements of satisfactory telephone service over extensive regions.

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M. Latour does not seem to be cognisant of the fact that high-vacuum three-electrode or audion tubes have been in *commercial service* since the summer of 1914 as telephone repeaters on the long-distance lines of the Bell Telephone System. It stands to reason that the use of such a device in such an intricate system of telephone communication, which involves lines stretching over several thousand miles, thus necessitating the use of several repeaters in series, must be preceded by a solution of the theory of operation of the device, the problem of its design, and the design of transformers and circuits with which the tube is to operate. The successful transmission of speech by radio telephone from Arlington, U.S., to Paris and Honolulu, in 1915, with a system which involved the use of high-power, high-vacuum, three-electrode tubes was the culmination of an extended series of investigations carried on by the engineers of the American Telephone and Telegraph Company and the Western Electric Company. The success of these experiments was the direct result of a thorough understanding on the part of these engineers of the theory of operation of the three-electrode tube as amplifier, detector, modulator, and oscillation generator.

The theory of the tube which I published was worked out by me in the winter of 1913 to 1914, and has been used ever since by the Western Electric Company in the design of tubes and their attending circuits. This work was based on careful investigations carried out by H. D. Arnold, during the years 1912 and 1913 on the characteristics of three-electrode tubes. (Langmuir and other engineers of the General Electric Company had also about that time studied the characteristics of three-electrode tubes, but this work was not known to me at the time I derived the amplification equations of the tube.) Furthermore, as early as 1914 I had established equations giving the relations between the electrical constants of the tube and its structural parameters. These equations have been used in the design of Western Electric tubes since then, and, as a matter of fact, the type of tube of which thousands are used to-day on the telephone lines of the Bell System has exactly the same electrical constants as the first tubes that were used commercially in 1914. In spite of this early work, I would, in justice to M. Latour, certainly have mentioned his 1916 paper in some of my publications, if I had known of it.

As regards the type of tube having a cylindrical structure placed horizontally above the press, and which M. Latour insists on calling a "French valve," I may say that this type of tube has exactly the same structure and arrangement as one of the very first types designed by me. My purpose in placing the structure horizontally above the press was merely to facilitate the manufacture. I have found, however, that it is not as good a structure as other Western Electric types by which it has been replaced some six years ago.

The tubes developed and manufactured by the Western Electric Company are not and have never been "tubes without high vacuum" or so-called "soft valves" as M. Latour states in a paper in the Société Française des Électriciens, 1919. These tubes are and have been from the beginning evacuated to such an extent that gas plays no part in the operation of the

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tube. The necessity for this condition was recognised by H. D. Arnold in 1912.

H. J. VAN DER BIJL.

New York, N.Y.,
March 16th, 1920.

The above letter has been submitted to M. Latour, who has replied as follows:—

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—I beg to call the attention of Mr. H. J. van der Bijl to the fact that any public claim of priority must be based on *published* documents such as papers or patent specifications.

Although I feel perfectly sure of the high personal ability of Mr. H. J. van der Bijl I cannot consider the fact that American engineers had built valve amplifiers for commercial use in 1914 as sufficient to prove beyond doubt that they had developed at that time the theory of the three-electrode valve now under discussion. I should say that any one working with valve amplifiers would be led after long tests to an amplification of telephonic currents. The intricacy of the system of telephone communication referred to by Mr. H. J. van der Bijl may introduce difficulties inherent to the use of repeaters on telephone lines but these difficulties are irrelevant to the theory under discussion.

As a matter of fact the operation of the three-electrode valve as an amplifier has been known since the issue of the American Patent No. 841387 of Lee de Forest in 1907, and the issue of the European Patents of von Lieben and Reisz. It was possible therefore for American engineers to disclose from 1907 to 1916 the *general* theory of the three-electrode valve expounded in my paper of 1916. As the American technical Press has been silent on this rather mathematical subject up to 1918 I consider my priority now recognised in American publications as being completely established.

MARIUS LATOUR.

Paris,
April 12th, 1920.

THE KALLIROTRON, AN APERIODIC NEGATIVE RESISTANCE TRIODE COMBINATION.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In Captain L. B. Turner's paper on the Kallirotron in your April issue an approximation is made which simplifies equation (16) into equation (17) on page 326 but which is not legitimate for the numerical values given on page 327 inasmuch as equation (16) makes $m = \infty$, while equation (17) gives $m = -8$.

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The author's point can, however, be proved in the following manner. If equation (16) is inverted, numerator and denominator multiplied by a_1a_2, a_1 replaced by $\alpha_1(1+e)$ and a_2 by $\alpha_2(1-e)$ as described on p. 327, and finally g/a replaced by ν, as suggested by Captain Turner in his letter in the March issue, we find

$$\frac{1}{m}=\frac{1+r_1\alpha_1+r_2\alpha_2-(\nu_1\nu_2-1)\,r_1r_2\alpha_1\alpha_2+(r_1\alpha_1-r_2\alpha_2)\,e+(\nu_1\nu_2-1)\,r_1r_2\alpha_1\alpha_2e^2}{\nu_1r_1\alpha_1+(\nu_2+1)\,\nu_1r_1r_2\alpha_1\alpha_2+\nu_1r_1\alpha_1e-(\nu_2+1)\,\nu_1r_1r_2\alpha_1\alpha_2e^2}$$

If the algebraical division is performed, we obtain

$$\frac{1}{m}=\frac{1}{\mu}+\frac{\left(r_1\alpha_1-r_2\alpha_2-\frac{\nu_1r_1\alpha_1}{\mu}\right)e+\left(\nu_1\nu_2-1+\frac{(\nu_2+1)\,\nu_1}{\mu}\right)r_1r_2\alpha_1\alpha_2e^2}{\nu_1r_1\alpha_1+(\nu_2+1)\,\nu_1r_1r_2\alpha_1\alpha_2+\nu_1r_1\alpha_1e-(\nu_2+1)\,\nu_1r_1r_2\alpha_1\alpha_2e^2}$$

where $\frac{1}{\mu}=\frac{1+r_1\alpha_1+r_2\alpha_2-(\nu_1\nu_2-1)\,r_1r_2\alpha_1\alpha_2}{\nu_1r_1\alpha_1+(\nu_2+1)\,\nu_1r_1r_2\alpha_1\alpha_2}$

μ has exactly the same meaning as in the paper, namely the amplification for infinitely weak signals.

As the two resistances r_1 and r_2 are independent, they may be adjusted so as to satisfy two conditions. Let one be to make μ as large as possible without endangering stability and the other to make $r_1\alpha_1-r_2\alpha_2-\frac{\nu_1r_1\alpha_1}{\mu}=0$

If we assume that e is so small that powers higher than the square may be neglected (e is of course not a voltage, but a ratio of voltages, and thus dimensionless), we finally get

$$\frac{1}{m}=\frac{1}{\mu}+\frac{\left(\nu_1\nu_2-1+\frac{(\nu_2+1)\,\nu_1}{\mu}\right)r_1r_2\alpha_1\alpha_2}{\nu_1r_1\alpha_1+(\nu_2+1)\,\nu_1r_1r_2\alpha_1\alpha_2}\,e^2$$

Under practical working conditions the coefficient of e^2 is positive, so that whatever the sign of e may be, $\frac{1}{m}>\frac{1}{\mu}$, or $m<\mu$.

G. BRAMWELL EHRENBORG.

Croydon,
April 9th, 1920.

The above letter has been submitted to Capt. L. B. Turner, who has replied as follows:—

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—Mr. Ehrenborg's criticism in his letter of the 9th inst. is justified. I regret I did not notice that, as he points out, the rough approximation by which expression (16) is simplified into expression (17) may lead to inconsistent results.

But it is not necessary to use expression (17) in order to arrive at a numerical demonstration of the limiter-amplifier property of the Kallirotron in the symmetrical case ($r_1=r_2=r$) investigated in my paper. We can

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calculate almost as simply from the accurate expression (16) directly. This is of the form

$$m = \frac{A + B}{C - B}$$

where A and C vary with the signal strength e, and when $e = 0$ are each very nearly equal to B, which does not vary with e. The exact values of A and B therefore do not matter, and we have only to examine the values assumed by m as C slightly changes under the action of the signal.

Retaining the approximation that $1/(1 - e^2) = (1 + e^2)$, and taking the numerical values of page 327 which make $B = \frac{64 \times 10^{10}}{49}$, expression (16) becomes

$$m = \frac{2B}{\frac{2B}{\mu} + e^2\left(\frac{1}{\alpha^2} + \frac{2r}{\alpha}\right)} = \frac{\mu}{1 + 0{\cdot}49\,\mu e^2}$$

where as before μ is the magnification with indefinitely weak signals. Therefore

$$me = \frac{\mu e}{1 + 0{\cdot}49\,\mu e^2}.$$

The formula reached at the top of page 328, from which Table 3 was calculated, is

$$me = \frac{\mu e}{1 + 0{\cdot}42\,\mu e^2}.$$

Hence Table 3 stands almost unchanged, the slight error there is being in the direction to disfavour the limiting effect.

Mr. Ehrenborg's analysis leads him to an unsymmetrical arrangement in which $r_1 \neq r_2$. Whether this is a useful arrangement can only be seen by carrying the calculation a little further than he has gone. He shows that in his arrangement $m < \mu$ whatever the sign of e (as is the case, of course, in my symmetrical arrangement); but for the limiter effect the more stringent condition must be satisfied that me reaches a maximum as e increases.

L. B. TURNER.

King's College, Cambridge,
April 23rd, 1920.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—Referring to the last paper of Mr. L. B. Turner in your issue of April, 1920, I beg to call the attention of your readers to my French patents No. 491186 (1915), and No. 501472 (1918).

In the last patent I describe an aperiodic resistance amplifier built with an even number of valves (two) and acting as a negative resistance, or more generally as a negative impedance of any desired nature, according to the accompanying diagram.

The plate batteries may be divided into two parts, one of which B_3 or B_3'

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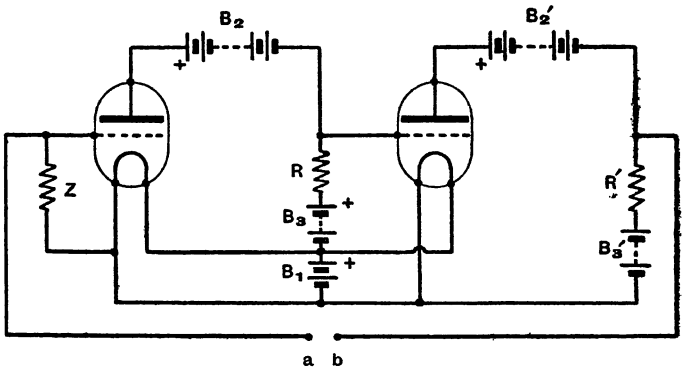
counterbalances the ohmic drop of the mean plate current in resistance R or R'. The nature and the value of the auxiliary impedance Z determine



the nature and the value of the negative impedance appearing between terminals a b.

I have been the first to introduce the idea of negative resistance in the conception of certain amplifier connections,—see also my earlier patents with Weintraub (1907).

MARIUS LATOUR.

Paris,
April 19th, 1920.

TRIODE NOMENCLATURE AND SYMBOLS.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—With reference to the letter of Captain Turner in the March issue of the RADIO REVIEW relative to Triode Nomenclature and Symbols, may I suggest that the letter g be associated preferably with the conception of electrical conductance where the voltage and current refer to the same circuit ? From this standpoint I am fully in accord with the suggestion of Captain Turner relative to his symbols g_g and g_a.

The notable suggestion of Mr. Appleton, relative to the function $\partial i_a/\partial v_g$ being called mutual conductance, is, I feel, a very beneficial one, but I would suggest similarly that the function $\partial i_g/\partial v_a$ be likewise distinguished as the *conjugate mutual conductance*. Such designation was employed in my paper on Triode Constants in the *Electrician* of January 9th, 1920. It would be in keeping with the above if such mutual conductances were distinguished by the character m rather than the character a as referred to by Captain Turner. Thus, I would write the mutual conductance of Mr. Appleton as m_a and the conjugate mutual conductance $\partial i_g/\partial v_a$ as m_g. The time has come when some more or less common system of nomenclature is essential to the art.

A. PRESS.

East Pittsburg, Pa.,
April 12th, 1920.

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THE
RADIO REVIEW

VOL. I JULY, 1920 NO. 10

Notes on the Theory and Calculation of Audio Frequency Valve Magnifiers.*

By J. K. CATTERSON-SMITH, M.I.E.E.

SYNOPSIS.

The article deals with troubles which arise through the self-capacity of the windings of transformers used in valve magnifiers. The theory of the valve and transformer coupling is developed and formulæ derived for use in calculating the windings and the size of the iron core. A first approximation for the capacity between layers is given.

The presence of capacity in the windings of the transformers used for coupling the valves in magnifiers is frequently a cause of difficulty in operation; this is especially the case when the magnifier is intended to be aperiodic.

There appears to be a scarcity at present of data for guidance in respect to the predetermination of this capacity and in consequence the decision as to the suitability or otherwise of a given transformer is usually made on empirical grounds. It is hoped that in the near future experimental data will be forthcoming so that more exact design may be carried out than is possible at present, the writer's experience being that the formula which is quoted below results in discrepancies between the calculated and the observed " self-capacity " of the windings.

A rough outline of the problem is set out below and some indication is given of the magnitude of the quantities; before proceeding to consider this it is advisable to review the conditions governing the design of the windings themselves for operation with a given type of valve.

The usual arrangement of the " intervalve " transformer is indicated in Fig. 1 for one stage of a magnifier. The magnification being obtained partly by the amplification at the valve and partly by the " step-up " of the transformer, the combination giving the voltage " step-up " per stage.

The number of turns in the windings for a given iron core depends upon

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* Paper received in final form March 29th, 1920.

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the valves with which the transformer is to be used, and it is most fortunate that the conditions are not so complicated as they appear.

The writer has made use of the now well-known valve characteristics to formulate the expressions given below for the design of the windings for the transformers suitable for the "hard" valves in common use.

It is well not to lose sight of the fact that the ever-present danger of oscillations due to "self-capacity" makes it most important not to over-estimate the closeness with which the design may be carried out.

The symbols employed for the valve characteristics are :—

k_1 = slope of "anode current—grid voltage" curve,

k_2 = slope of "anode current—anode voltage" curve,

k_3 = slope of "grid current—grid voltage" curve,

k_4 = slope of "grid current—anode voltage" curve,

and $m = k_1/k_2$.

Referring to Fig. 1 it will be seen that the load on the secondary of the

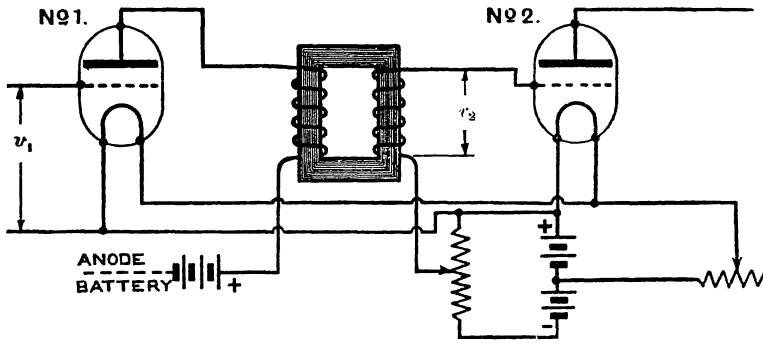

FIG. 1.

transformer is the alternating grid-current, taken by the second valve, at the alternating grid-voltage v_2 and this depends upon the slope k_3 of "the grid current—grid voltage" characteristic. The load is determined, therefore, by the resistance $R_g = 1/k_3$ if any small effects due to "k_4" are ignored.

The resistance of the load R_g appears in the primary side of the transformer as $R_g \cdot \frac{1}{r^2}$ where r is the transformation ratio or (secondary turns)/(primary turns) for an iron-cored transformer.

The total primary current is made up of two components at $\frac{1}{4}$-period phase difference, viz., i_μ the magnetising current lagging 90° to the primary voltage and i_w the load component which is in phase with the primary voltage. The primary voltage is the alternating anode voltage V.

Thus the anode current is :—

$$I = \sqrt{i_w^2 + i_\mu^2} = \frac{V}{Z} \text{ lagging by the angle } \phi$$

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where $\cos \phi = \dfrac{Z \cdot r^2}{R_g}$ and Z is the equivalent impedance of the loaded transformer, or

$$Z = 1 \div \sqrt{\left(\frac{r^2}{R_g}\right)^2 + \left(\frac{1}{\omega L}\right)^2}$$

The above conditions are represented by the " equivalent circuit " diagram

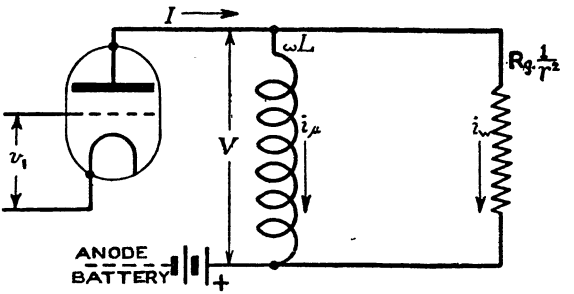

FIG. 2.

of Fig. 2 and the phase relations are as shown in Fig. 3. It is clear that the anode current lags by ϕ to the anode alternating voltage and a little consideration of the problem will show that the anode current lags by a different

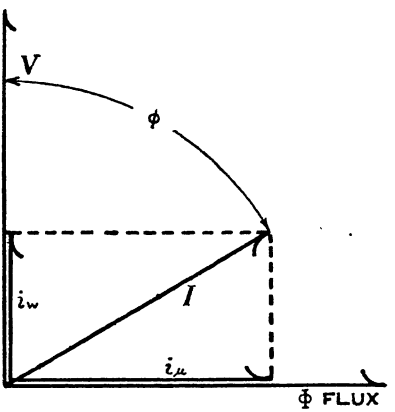

FIG. 3.

angle, viz., ψ to the alternating grid-voltage; this relationship is indicated in Fig. 4.* The instantaneous values in terms of k_1 and k_2 for the valve are therefore expressed by :—

$$I_{inst} = k_1 v_{inst} - k_2 V_{inst} \quad \ldots \ldots \ldots \quad (1)$$

in which $I_{inst} = I_{max} \cdot \sin \theta$

$v_{inst} = v_{max} \cdot \sin (\theta + \psi)$

*The vector v representing the " grid-voltage " is really at 180° to the position shown in Fig. 4.

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$$V_{inst} = V_{max} \cdot \sin(\theta + \phi)$$

and $$V_{max} = I_{max} \cdot Z.$$

The foregoing relations may be substituted in equation (1) to find at what value of θ the grid voltage attains its crest value and it is found that the grid voltage is a minimum when

$$\theta = \tan^{-1}\left\{\frac{1}{k_2 Z} + \cos\phi\right\} \div \sin\phi \quad \ldots\ldots\ldots (2)$$

Calling this value θ_1 gives $\psi = (90 - \theta_1)$.

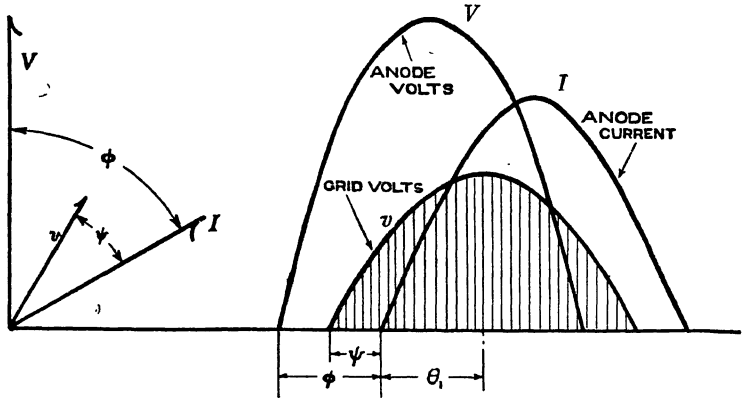

FIG. 4.

The amplification at the valve is the ratio of the alternating anode voltage to the alternating grid voltage or $\frac{V}{v}$ and the voltage at the grid of the succeeding valve is r times greater, thus the voltage "step-up per stage" is $r \cdot \frac{V}{v}$ which is denoted by the symbol Y. Putting m for k_1/k_2 it is a simple matter to derive from equation (1) the voltage step-up per stage

$$Y = m \cdot r \cdot \left[\frac{Z \cdot \cos\psi}{\frac{1}{k_2} + Z\cos\phi}\right]$$

and then substituting for ψ and ϕ the step-up is

$$Y = \frac{m \cdot r}{\sqrt{1 + \frac{1}{(k_2 Z)^2} + \frac{2r^2}{k_2 R_g}}} \quad \ldots\ldots\ldots (3)$$

The graphs of this equation for various values of reactance ωL show that the step-up Y reaches a maximum for a definite ratio r.

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Two cases are of interest :—

Case I.—When ωL is infinite the step-up attains its crest value when $r = \sqrt{k_2 R_g}$ or $\sqrt{k_2/k_3}$ and then

$$Y_{crest} = \tfrac{1}{2}\, m \,.\, r \quad \ldots\ldots\ldots\ldots \quad (4)$$

With ordinary valves this may be a good deal greater than the amplification obtained with a plain resistance coupling which approaches m as its limiting value.

The magnetising current is zero and both $\cos\phi$ and $\cos\psi$ are unity ; the transformer behaving as an "ideal" transformer giving the theoretical upper limit of the magnification per stage for an aperiodic magnifier.

Equation (4) will be found of use for gauging the possibilities of a given valve for use as a magnifier and for general work as an approximation avoiding the more cumbersome equations of the following case.

Case II.—The practical value of the reactance ωL is of the order of 50,000 or 100,000 ohms and then the step-up must be calculated by means of equation (3) for which the correct value of the transformation ratio, by putting $\dfrac{dY}{dr} = 0$, is found to be

$$r = \sqrt[4]{(k_2 R_g)^2 + \left(\frac{R_g}{\omega L}\right)^2} \quad \ldots\ldots\ldots \quad (5)$$

The graphs for low values of ωL, given by equation (3), are flattened and consequently the magnification is not nearly so sensitive to r, nevertheless r is always lower than might be expected and in practice appears limited to about 5 or 10 as an outside figure.

In the foregoing treatment the effect of resistance drop and drop due to magnetic leakage has been left out of consideration for the sake of simplicity and because it seems that with the smallest gauges of copper wire the resistance can be made negligible. The same applies to the leakage drop at the exceedingly low values of the field strength in the magnetic circuit. The presence of drop in the transformer from either of these causes is of course detrimental to the performance of an aperiodic magnifier from the point of view of magnification.

The step-up Y_{max} obtained from equations (3) and (5) will be a reasonable percentage of Y_{crest} only if ωL is made sufficiently large. With constants for the valves such as $k_1 = 300 \times 10^{-6}$, $k_2 = 30 \times 10^{-6}$ and $k_3 = 1 \times 10^{-6}$ amp./volt, or $Y_{crest} = 27$, it is essential that ωL should not be less than 50,000 ohms which for $\omega = 5{,}000$, or 800 cycles per second, means an inductance of 10 henries in the primary winding. This large inductance can be obtained with very small transformers by the use of some thousands of turns. The following expression is useful in this connection :—

the inductance $L = \Phi \times \text{turns} \div i_\mu \,.\, 10^{-8}$ henries and as

the density $\quad B = \mu \times \dfrac{4\pi}{10} \,.\, i_\mu \,.\, \dfrac{\text{turns in winding}}{\text{length of iron path}}$ this reduces to

$$L = \frac{4\pi}{10} \,.\, \mu \,.\, \frac{\text{iron section}}{\text{iron length}} \,.\, (\text{turns})^2 \,.\, 10^{-8} \text{ henries} \quad \ldots\ldots \quad (6)$$

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With ordinary alloyed transformer steel μ is of the order of 200 to 300 at these low magnetisations. It may be remarked that with ωL as small as $0{\cdot}05 \times 10^6$ ohms the magnetising current is only 20 micro-amperes per volt and the value of the magnetising force (H) less than a thousandth of unity.

The best form of core to satisfy equation (6) is one having a high ratio of section to length of iron path; such a condition is best met by the ordinary

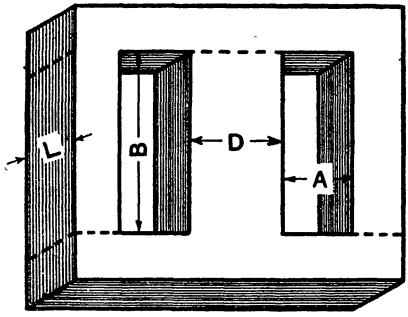

FIG. 5.

"shell type," Fig. 5, with a square window, *i.e.* $A = B = D = L$. With very small gauge wire the circular form of coil is imperative and this together with considerations of convenience in shape leads to the proportions $A = 0{\cdot}5$ to $0{\cdot}75D$, $B = 2$ to $3D$, and $L = D$ with a chamfer if desired. Thus $ABDL = 1$ to $2\frac{1}{4} \times D^4$ which gives the leading dimensions from :—

$$A.B.D.L = \frac{0{\cdot}45 \times \text{mV} \times \text{mA}}{f \times f_i \times f_c \times \Delta \times B_{max}} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where the dimensions are in centimetres,

and mV = alternating milli-volts (r.m.s.) on primary.
mA = total primary current in milli-amps.
f = cycles per second.
f_i = iron space-factor, 70 per cent. to 90 per cent.
f_c = copper space-factor, 20 per cent. approx.
Δ = primary current density amps./sq. mm.
B_{max} = flux density per sq. cm.

From the above it is clear that the number of primary turns will be of the order of 5,000 or 10,000 which produces sufficient capacity to cause resonance at moderate frequencies, sometimes dangerously near to the audio frequency at which the coil is working.

The winding may be regarded as consisting of an inductance L, a resistance R and a capacity C_s in series, see Fig. 6, and the problem is to determine the capacity C_s. This is made up of the capacity between layers and between turns. The former appears to be the chief source of the capacity C_s which gives trouble at audio frequencies and it only is considered in the following.

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Treating each layer as though it consisted of square section conductor in place of circular wire with a distance t cm. between the layers and n layers

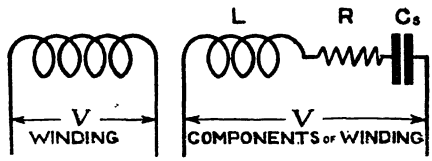

FIG. 6.

of dielectric, Fig. 7 represents a section of two of the layers in a coil of axial length B. The voltage per layer of dielectric is V/n and the voltage at any elementary section distant x cms. from the junction of the layers

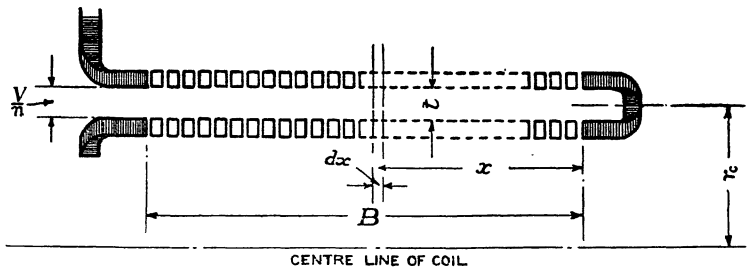

FIG. 7.

is $\frac{V}{n} \times \frac{x}{B}$. If the mean radius of the whole coil is r_c the capacity of the elementary section is $\frac{2\pi \cdot r_c \cdot dx}{4\pi t} = \frac{r_c}{2t} \cdot dx$, and the charging current for the whole layer $= \omega \cdot V = \cdot C_s = \int_{x=0}^{x=B} \omega \cdot \frac{V}{n} \cdot \frac{x}{B} \cdot \frac{r_c}{2t} \cdot dx = \omega \cdot V \cdot \frac{r_c \cdot B}{4n \cdot t}$

thus the self-capacity with a dielectric constant other than 1·0 is :—

$$C_s = k \cdot \frac{r_c \cdot B}{4n \cdot t} \times 1{\cdot}1 \times 10^{-6} \text{ mfd} . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

This of course depends upon the validity of some rather broad assumptions of which the most serious is that the charging current does not alter the distribution of the potential along the layers. The writer has no experience of the use of a more exact expression and as has been mentioned previously the capacity given by equation (8) does not invariably tally with that observed by means of such a test as is indicated in Fig. 8. The method is to set the supply frequency at any desired value by adjustment of C_1 and then alter C_2 until maximum noise is given by the telephone in series with the

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transformer under test. Plotting the relation between C_1 and C_2 gives a straight line cutting the base; and if this is extended to intersect the vertical axis the intercept is the value of the capacity C_s. This is shown in Fig. 9.

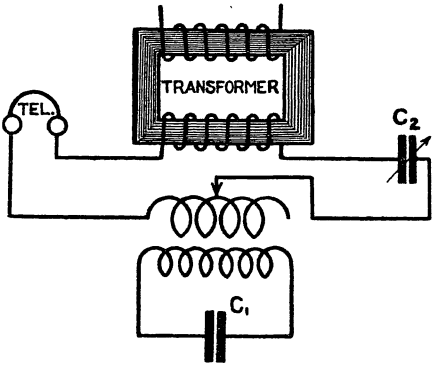

FIG. 8.

As an example of the magnitude of this capacity consider a coil of mean radius 2·0 cms. having 12 layers 5 cms. in length and $t = 0{\cdot}0030$ cm. for a very light cotton spacing between layers. If the coil is impregnated with

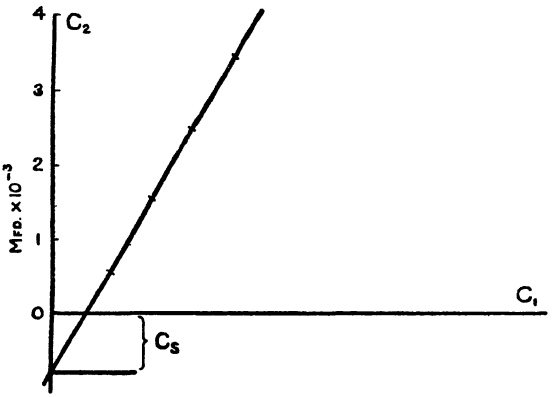

FIG. 9.

paraffin wax the dielectric constant is approximately 2·0, then equation (8) gives the self-capacity as :—

$C_s = 305 \times 10^{-6}$ mfd. or 0·30 milli-mfd. to which must be added the parallel self-capacity of the secondary making a total of approximately 0·6 milli-mfd. It is scarcely necessary to add that the turns should be kept down and impregnation of the coils avoided, whilst enamel-covered wire does not appear to possess any great advantage over silk-covered wire. Consistent results are hardly to be expected unless the coils are machine wound.

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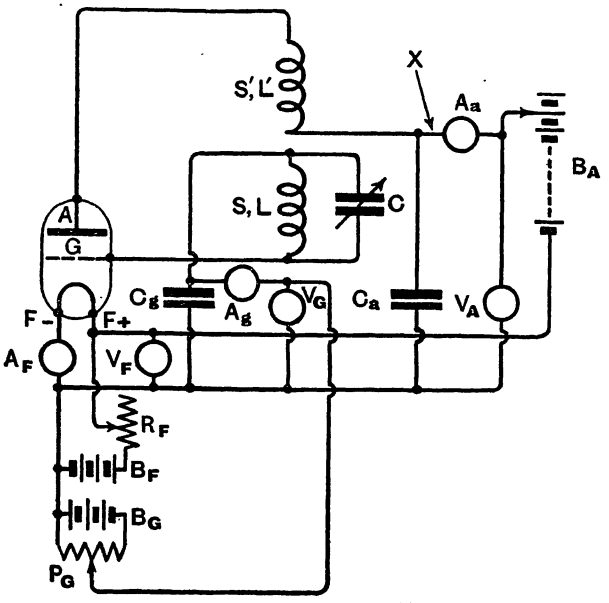
On the Effect of Changes in Filament Temperature, Grid Potential and Anode Potential on the Frequency of the Oscillations Generated by a Thermionic Valve.*

By W. A. LEYSHON, B.Sc.

INTRODUCTION.

The experiments to be described† were undertaken in order to find out whether (1) a change in the circuit conditions of an oscillating valve produced any change in the frequency of the oscillations generated—the oscillating circuit maintained by the valve being otherwise left unchanged, and (2) when it had already been established that such changes occurred, to discover to what extent they occurred and in what ways the various causes were related to the effects produced.



A anode.
G grid.
F+ positive end of filament.
F− negative end of filament.
L′ anode coil. [Resistance S′.]
L grid coil. [Resistance S.]
R_F filament circuit resistance.
P_G grid potentiometer.
C variable condenser in grid circuit.
C_a condenser of large capacity shunting B_A and V_A.
C_g shunting condenser in grid circuit.
V_A, V_G, V_F anode, grid and filament voltmeters.
A_a, A_g, A_F anode, grid and filament ammeters.
B_A, B_G, B_F anode, grid and filament batteries.
A_a millivoltmeter.
A_g shunted unipivot galvanometer.

FIG. 1.

* Received May 3rd, 1920.

† These experiments were in progress before the publication of the paper by Dr. W. H. Eccles and Dr. J. H. Vincent, entitled, "On the Variations of Wavelength of the Oscillations generated by Three-Electrode Thermionic Tubes due to Changes in Filament Current, Plate Voltage, Grid Voltage or Coupling" (*Proceedings of the Royal Society*, 96A, pp. 455—465, February 3rd, 1920).

The circuits used were different and the frequency of the oscillations was very much greater (of the order of 10^7 per second) in this case.

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It was expected that such changes would be small, and a sensitive method of detecting them was therefore required.

DESCRIPTION OF APPARATUS.

The apparatus used consisted of two high frequency oscillating sets A and B, which could be made to heterodyne. A diagram is given (Fig. 1) showing the circuit arrangements in B. A differed from B in that a pair of high resistance telephones was inserted at X. It was in some cases found desirable to insert the telephones in a corresponding point in B.

In the actual experiments the condenser C was of very small capacity. In order to calibrate this a variable condenser C_1 of larger capacity was placed in parallel with it in circuit A and sufficient capacity introduced into circuit B to make it possible to obtain a heterodyne note with A. The condenser C_1, which had previously been calibrated by a bridge method using a vibration galvanometer, was then set at successive known values and C adjusted until the circuits were in tune. The calibration of C was thus carried out by a substitution method.

The coupling between the oscillation coils of A and B was adjusted to be so small that on bringing B into tune with A the resonance point was very definite, and an exceedingly small range of capacity (about $\frac{1}{100}$ $\mu\mu$ F) was sufficient to cover the "silence space."

METHOD OF USING THE APPARATUS.

The condenser C having been calibrated C_1 was removed and the circuits again made to heterodyne.

It was found that on increasing the filament temperature of valve B the heterodyne note entirely disappeared and a new adjustment of C in the direction of diminished capacity was necessary in order to bring the circuit into resonance with A.

The changes in effective capacity of the valve resulting from changes in filament temperature could thus readily be measured. (The term "effective capacity" may perhaps be regarded as legitimate, in that the changes of frequency produced by altering valve conditions may be counteracted by a change of capacity of the tuning condenser.)

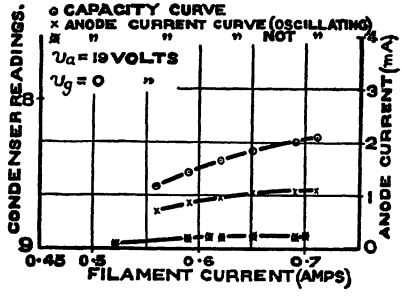

FIG. 2.

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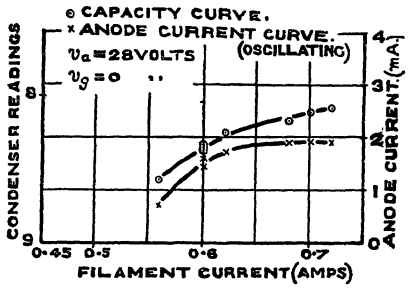

FIG. 3.

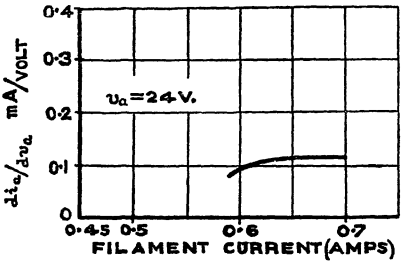

FIG. 4.

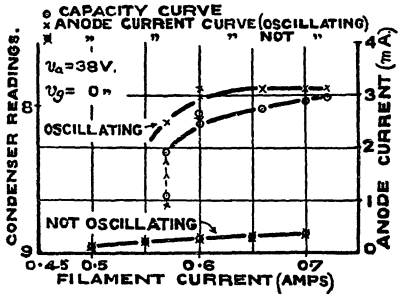

FIG. 5.

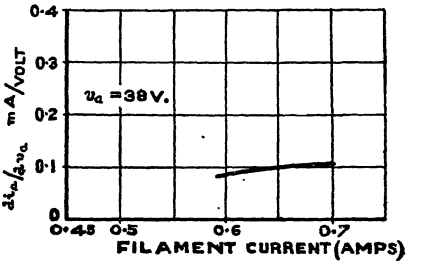

FIG. 6.

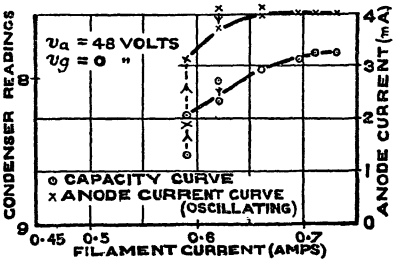

FIG. 7.

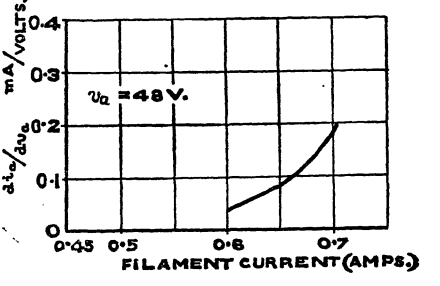

FIG. 8.

For given values of the anode and grid voltages, curves were obtained for valve B showing the variations in the value of the capacity of the balancing condenser C with increasing filament current—the frequency of the oscillations generated being kept constant.

RESULTS.

Several valves were tested and although the actual shape of the curve between capacity and filament temperature for a given anode and grid potential depended on the valve used, similar changes in the shape of the curves always resulted on altering these potentials.

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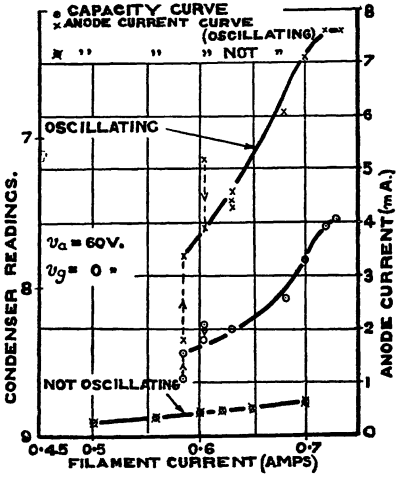

FIG. 9.

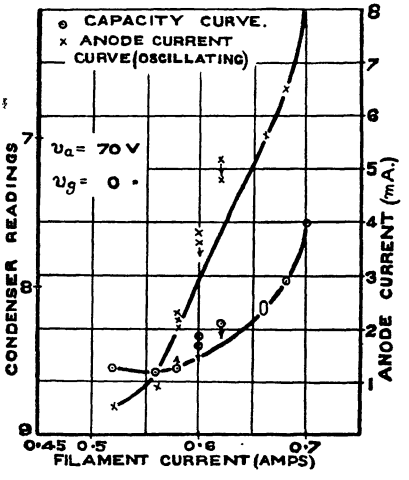

FIG. 10.

A set of curves is given in Figs. 2—10 for a valve of the Osram B type, showing variations in capacity, and in anode current, with filament temperatures. For comparison, corresponding values of anode current obtained with the reaction coil cut out—*i.e.* with the valve not oscillating, are also shown.

The curves showing variation in grid current with increasing filament temperature are shown in Fig. 11. The grid current with the non-oscillating valve was negligible compared with that taken when the valve was oscillating.

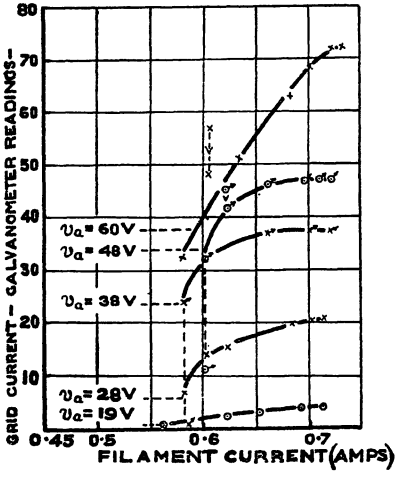

FIG. 11.

It will be seen that the scale for condenser readings is inverted so that a point higher up on the graph corresponds to a lower reading of the condenser—the curves were drawn in this way to facilitate comparison with the anode current curves and with the curves shown in Figs. 4, 6, and 8. These latter show the variation of the (oscillating) anode current with anode voltage for different filament temperatures and were obtained from the other curves.

Curves obtained for the same valve after reducing the reaction coil—no alteration being made in the coupling—are shown in Figs. 12—14. It will be noticed, referring to Figs. 2—11, that:—

(1) The slope of the capacity—filament-current curve is, for low anode

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voltages, greatest at low filament temperatures. (In the curves obtained for another valve, the capacity of the condenser C definitely approached a lower limit at high filament temperatures.)

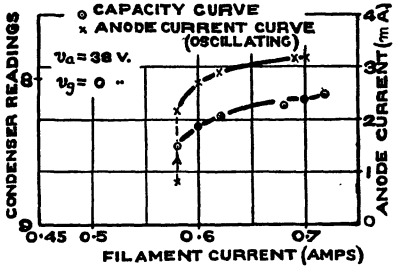

FIG. 12.

On the other hand, with higher anode voltages the slope of the capacity curve is least at low filament temperatures.

Similar changes in the shape of the capacity—filament-current curve have been observed in the case of every other valve tested under the same circuit conditions.

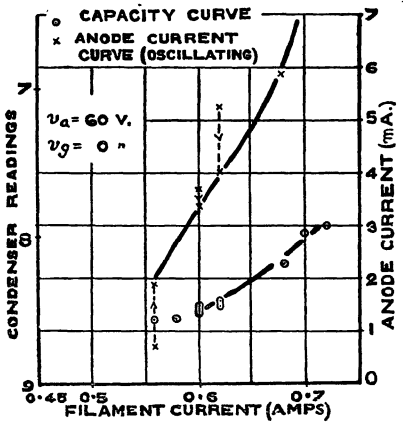

FIG. 13.
Curves with Reaction Coil reduced.

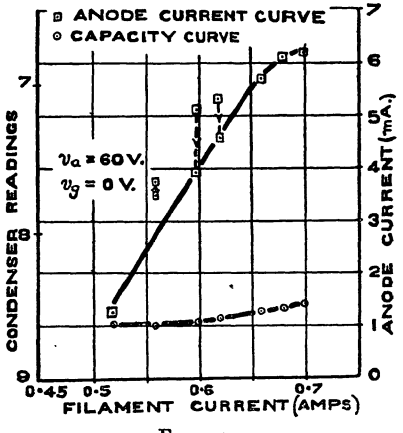

FIG. 14.
Curves with Reaction Coil still further reduced (no alteration in coupling between anode and grid coils).

(2) For this particular valve there is a certain amount of instability at a temperature corresponding to a filament current of about 0·58 ampere; some time elapses before the frequency of the oscillation for a particular condenser setting is constant. A corresponding effect is noticed in the anode and grid current curves. It occurs at points where a small change of filament temperature produces a large change in the anode and grid currents.

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(3) The steepness of the anode and grid current curves as compared with that of the corresponding curves obtained for the non-oscillating valve is very marked. (See Fig. 9.)

(4) The anode and grid current curves for the oscillating valve follow each other very closely.

Referring to Figs. 12—15, it is seen that :—

(1) The effect of reducing the reaction coil is to reduce greatly the slope of the capacity—filament-current curve. (See Figs. 13 and 14.)

(2) The grid currents are less than those for corresponding voltages with a larger reaction coil. (See Figs. 11 and 15.)

(3) The anode current is not reduced to the same extent as the grid current on reducing the reaction coil and leaving the other conditions unchanged.

Other curves are given (see Figs. 16 and 17) showing the effect on the capacity curve of raising the grid voltage.

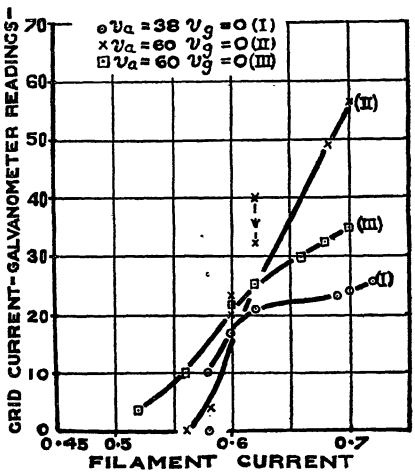

FIG. 15.

Grid Current Curves.

Curve I. corresponds with Fig. 12.
„ II. „ „ Fig. 13.
„ III. „ „ Fig. 14.

It is evident that the shape of the curves showing the relation between grid voltage and capacity will be different for different anode voltages and filament temperatures.

Similarly a series of curves anode-voltage—capacity would have to be drawn for different grid voltages and filament temperatures in order to express completely the relation between these quantities for a given valve and associated circuit.

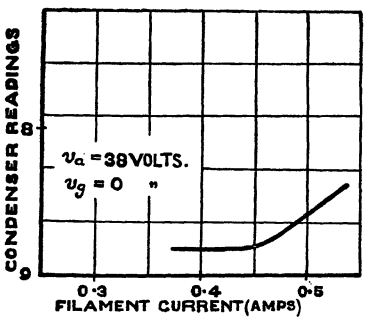

FIG. 16.

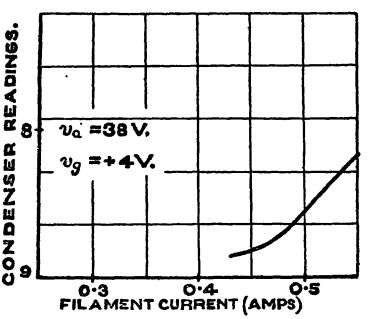

FIG. 17.

Curves for V. 24 Valve showing effect of raising the Grid Voltage.

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DISCUSSION OF RESULTS.

The observed changes of frequency due to altering the circuit conditions of the valve may be due to :—

(1) An alteration in the values of the various "conductances" of the valve, *i.e.* of the quantities $\frac{\partial i_a}{\partial v_g}$, $\frac{\partial i_a}{\partial v_a}$, $\frac{\partial i_g}{\partial v_g}$ and $\frac{\partial i_g}{\partial v_a}$, where v_a, v_g represent anode and grid voltages and i_a, i_g anode and grid currents respectively.

(2) An actual change of capacitance between the valve electrodes. (It is possible that the inductivity of an electron atmosphere, such as that which exists in a very hard valve, is not the same as that of a vacuum; in a soft valve all gas molecules will tend to collect in the space charge region at high filament temperatures where they would tend to increase the inductivity of the grid-filament space. This effect, however, would probably be far too small to need consideration.)

It was suggested that the expansion of the filament wire might cause it to move appreciably nearer to the grid, and thus alter slightly the effective capacity; by throwing an enlarged image of the filament on a screen it was found that the movement amounted to about 0·3 mm. when the filament voltage was altered from 1·4 to 4 volts; this movement is not sufficient to account for any large part of the changes in effective capacity that have been observed.

To show how the value of $\frac{di_a}{dv_a}$ affects the frequency of the oscillations generated :—

Let L = Grid circuit inductance (of the order of 20μH).
S = Grid circuit resistance (of the order of 1·5 ohm).
C = Grid circuit capacity (of the order of 20$\mu\mu$F).
L' = Anode circuit inductance (of the order of 20μH).
S' = Anode circuit resistance (of the order of 2 ohms).
i = Variable part of current in grid oscillatory circuit.
v_g = Variable part of voltage on grid.
i_a = Variable part of current in anode circuit.
v_a = Variable part of voltage on anode,

and let the variable part of the current to the grid in the valve be neglected.

Then

$$v_g = \frac{1}{C}\int i.dt \quad \ldots\ldots\ldots \quad (1)$$

$$L.\frac{di}{dt} + Si + \frac{1}{C}\int i.dt - M.\frac{di_a}{dt} = 0 \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$L'\frac{di_a}{dt} + S'i_a + v_a - M.\frac{di}{dt} = 0 \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$\text{also } i_a = av_a + gv_g \quad \text{whence } v_a = \frac{i_a - \frac{g}{C}\int i.dt}{a} \quad \ldots\ldots \quad (4)$$

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where, $a = \frac{di_a}{dv_a}$ and $g = \frac{di_a}{dv_g}$.

On solving these equations we obtain

$$\omega^2 (M^2 - LL') + \frac{L'}{C} + SS' + \frac{S}{a} - \frac{Mg}{Ca} = 0 \quad \ldots\ldots \quad (5)$$

$$\omega^2 \left(SL' + S'L + \frac{L}{a}\right) = \frac{S'}{C} + \frac{1}{aC} \quad \ldots\ldots \quad (6)$$

For tight coupling $M^2 - LL' =$ (approximately) 0.

$$\therefore \frac{L'}{C} + SS' + \frac{S}{a} - \frac{Mg}{Ca} = 0 \quad \ldots\ldots\ldots\ldots \quad (7)$$

gives the condition for oscillation.

From (6) $$\frac{1}{\omega^2} = LC + \frac{SL'C}{S' + \frac{1}{a}}$$

i.e. $$\frac{1}{\omega^2} = LC + \frac{aSL'C}{1 + aS}$$

$$= LC + aSL'C \text{ approximately, since } aS \text{ is of the order } 10^{-3} \quad \ldots \quad (8)$$

Hence if L, C, M, S' are constant, an increase in a will lower the frequency.

In the experiments described ω was kept constant.

On differentiating (8) with respect to filament temperature we obtain

$$L.dC + aSL'.dC + SL'C.da = 0.$$

The second term is negligible in comparison with $L.dC$.

Hence to a first approximation

$$-L.dC = SL'C.da.$$

In the experiments described

L	was of the order of	20μH	$= 20 \times 10^3$ e.m. units.
dC	,, ,,	$\frac{1}{4}\mu\mu F$	$= \frac{1}{4} \times 10^{-9} \times 10^{-12}$ e.m. units.
C	,, ,,	$20\mu\mu F$	$= 20 \times 10^{-21}$ e.m. units.
S	,, ,,	1·5 ohm	$= 1{\cdot}5 \times 10^9$ e.m. units.
L'	,, ,,	$20\mu H$	$= 20 \times 10^3$ e.m. units.
da	,, ,,	$0{\cdot}16 \times 10^{-12}$	e.m. units.

then the left-hand side of the equation $= 20 \times 10^3 \times \frac{1}{4} \times 10^{-21}$;

$= 5 \times 10^{-18}$

and the right-hand side $= 1{\cdot}5 \times 10^9 \times 20 \times 10^3 \times 20 \times 10^{-21} \times 0{\cdot}16 \times 10^{-12}$

$= 1 \times 10^{-19}$.

Thus it is seen that the change in effective capacity is greater than that which would be expected from a change in the value of a.

The curves show that decreasing the reaction coil L' reduces the change in effective capacity produced by altering the filament temperature—the other circuit conditions remaining unaltered. This would be expected from the relation $L.dC = L'SC.da$.

When oscillations of large amplitude are taking place the grid conductance becomes appreciable and this grid conductance, in addition to the anode

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conductance, exercises a damping effect on the grid oscillatory circuit. The effect of the grid conductance has been considered in the case of a valve used as an amplifier or rectifier by E. V. Appleton,* who showed that minimum damping could be obtained by choosing a condenser of suitable capacity for the circuit.

The effect of the increasing grid current is to make the potential oscillation greater on the negative than on the positive side; the mean grid potential is therefore more negative as the filament temperature is raised, making it possible for the "space charge" to be formed at lower temperatures than for the non-oscillating valve with zero grid potential. This is shown in the curves given by the anode and grid currents approaching an upper limit (for lower voltages) as the filament temperature is raised.

The anode circuit itself may be considered as an oscillatory circuit, since there is a certain amount of capacitance between the anode and the filament of the valve. The actual frequency of the oscillations generated will therefore depend on the natural frequencies of the two oscillatory circuits and on the coupling between them.

Since the actual changes of anode current produced by altering the filament temperature are always much greater than those of the grid current, it would be expected that the natural frequency of the anode oscillatory circuit would undergo larger changes than that of the grid circuit. It would therefore appear that smaller changes in the frequency of the oscillations generated are likely to occur if the oscillatory circuit is connected to the grid of the valve than if it is connected to the anode—provided that the reaction coil is sufficiently small.

SUMMARY OF RESULTS.

(1) When an oscillatory circuit is maintained by a thermionic valve—the circuit being connected to the grid of the valve—changes in the effective capacity of the valve are observed on altering the filament temperature.

(2) On increasing either the steady voltage applied to the anode or that applied to the grid of the valve, these changes in effective capacity are increased.

(3) A reduction of the inductance of the reaction coil without altering the coupling between it and the oscillatory circuit causes a very appreciable diminution in the changes of effective capacity observed.

(4) The changes—which, in the arrangement employed, correspond to changes in effective capacity of the order of $0{\cdot}5\mu\mu F$—apparently are not wholly accounted for by changes in the values of the "conductances" of the valve.

The experiments described have been carried out in the Laboratories of Applied Electricity, University of Liverpool. My thanks are due to Professor E. W. Marchant, D.Sc., for his help and advice during their progress.

* E. V. Appleton. "Note on the Effects of Grid Currents in Three Electrode Ionic Tubes." *Philosophical Magazine*, 37, pp. 129—134, January, 1919.

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The Generation of Large Powers at Radio Frequencies.

By THE EDITOR.

There was a stage in the development of the low-frequency alternate current generator when the outstanding feature was diversity of design. Armatures were sometimes inside and sometimes outside the field system; the outside member was generally fixed, but in some cases, as at Niagara, the inside member was fixed and the outside member rotated around it. There was the Lauffen type with claw-poles, the Mordey Victoria with a stationary disc armature, the Ferranti with a rotating disc armature and various types of inductor alternators. With time came a gradual elimination and standardisation, modified only to suit the changing conditions due to the introduction of the steam turbine and the gradual growth in the size of the units. The early types are now only found in museums and technical colleges, and new machines, whether built in this country, in America, in France or in Germany, are very similar in the general design, however they may differ in detail.

If at the present time it is decided to build a transmitting station for radio-telegraphy over several thousand miles, it is necessary to erect an aerial with a height say of 500 feet, and a capacity of 0·01 to 0·05 microfarad, and to supply this aerial with from 100 to 300 kilowatts at a frequency of 15,000 to 25,000 cycles per second with the provision of a suitable arrangement for signalling. There are several different methods in use at the present time for meeting these requirements, but it is obvious that they cannot all be of equal merit and it is a matter of some importance to determine as soon as possible which is the best method. If all the wireless telegraph companies in the world were to pool their experience and resources and be uninfluenced by considerations of patent rights and national prejudices, which system would be employed? Although the synchronous spark and the quenched spark appear to have been superseded for such large powers, the timed-spark system of the Marconi Company has recently been installed at the Norwegian transatlantic station at Stavanger. Arc generators have been carrying a large part of the transatlantic traffic between the United States and France and Italy and the new station at Bordeaux is being fitted with a 1,000 kilowatt arc supplied by the Federal Poulsen Company of America. An Alexanderson disc-inductor alternator generating directly the requisite frequency has been working at the New Brunswick station for some time, and no one can listen to the constant pitch of the note as received by the beat method without admiring the extremely accurate speed regulation. At Lyons the Société Française Radio-électrique have recently installed an inductor alternator of a different type, connected directly to the aerial and delivering thereto over 200 kilowatts. We understand that two 500 kilowatt machines of the same type are to be installed at Bordeaux. If this be so, arcs and high-frequency machines will be working side by side both at Lyons and Bordeaux. At Eilvese, near Hanover, the Goldschmidt internal cascade machine has worked throughout

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the war and is still in continuous operation. At Nauen the Telefunken Company has recently installed a new high-power plant consisting of an alternator giving 6,000 cycles per second, connected to the aerial through two frequency doubling transformers in cascade, thus giving 24,000 cycles per second.

In addition to these half-dozen alternative systems all in actual operation, there is always the three-electrode valve, awaiting the successful design of a high-power type, but remaining for the present a matter of pious hopes and less pious rumours.

It will be seen that there is far greater diversity at the present day in the methods of generating high frequency currents than there ever was in the methods of generating low frequency currents, and there is little doubt that the future will see the elimination of some of these methods and the gradual improvement and standardisation of others.

It is probable that the power supplied to the aerial has now reached the highest value which will be required and that, with a higher efficiency of radiation of the transmitting aerial, and with greatly improved methods of eliminating atmospheric disturbances, and thus being enabled to use increased amplification, smaller transmitting powers will be found sufficient. For the present, however, the power required is several hundred kilowatts and the time seems ripe for a careful non-partisan comparison of the relative advantages and disadvantages of the various methods at present employed to produce this power.

High Frequency Alternators.*

By MARIUS LATOUR.

The author pointed out that the various types of high frequency alternator may be classified as follows :—(1) machines in cascade, (2) internally-cascaded machines, (3) homopolar disc machines (4) variable reluctance alternators, and (5) alternators using only a part of the armature periphery. Of these the paper dealt in particular with the last two classes, the general treatment following the lines of a previous paper by the same author.†

At the conclusion of the lecture the author briefly considered the conditions of maximum efficiency for machines of this type. The various methods of speed regulation were briefly touched upon, including the use of a second machine mounted upon the same shaft and so arranged that it is loaded to the same extent that load is removed from the H.F. alternator when signalling, but the author was of the opinion that the most satisfactory solution was to be obtained with some form of vibrating contact speed regulator controlling the speed of the driving motor. Finally the conditions under which H.F. alternators may be run in parallel were developed by the aid of vector diagrams, and the best condition was proved to be when the reactance of the machine was equal to its resistance. This condition may be most easily secured when a condenser is inserted in series with each machine.

In the discussion Professor Field gave some interesting particulars of machines for 600 cycles, which was, of course, quite outside the range of frequencies contemplated in the paper. Other speakers discussed the question of the relative merits of valve and alternator transmitters from various points of view. It was also suggested that the question of alternator development was wrapped up in that of the receiver development. If receiving circuits can be devised which have a very minute decrement a much more exact speed regulation of the H.F. alternator will become necessary.

* Abstract of paper read before the Wireless Section of the Institution of Electrical Engineers on June 9th, 1920.

† *Bulletin de la Société Française des Électriciens*, 9, pp. 97—114, February, 1919. (Abstracted in *Wireless World*, 7, pp. 187—190, July, 1919, and pp. 247—248, August, 1919.)

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Some of the Problems of Atmospheric Elimination in Wireless Reception.*

By PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

The object of this paper was to indicate some of the solutions which have been put forward on various occasions with a view to eliminating or reducing the effects of atmospheric disturbances in wireless receivers. After a brief introduction dealing with the nomenclature and classification of atmospherics, the fundamental electrical differences between atmospherics and C.W. or spark signals were indicated by means of a series of oscillograms, while the different effects produced in a tuned secondary circuit were also shown by means of a radio receiving apparatus subjected to the influence of signals from a "tonic-train" valve transmitter, together with irregular "X" impulses manufactured artificially by discharges from a condenser of large capacity. These differences are the basis of all the various methods that have been devised for eliminating atmospheric impulses. The effect of coupling and the advantages of a so-called "aperiodic" aerial receiver were then pointed out, and the various methods of atmospheric elimination classified as follows :—(1) Intensity limiters ; (2) Directional reception methods ; (3) Filtering circuits and (4) Methods dependent upon the aerial form.

One of the earliest intensity limiters was Austin's silicon-arsenic contact. This has been succeeded by the dimmed valve limiters in modern receivers. A recent addition to this class of limiter is L. B. Turner's Kallirotron limiter.†

As regards directional reception its chief advantages lie in somewhat limiting the areas from which atmospherics are received. The balanced aerial receivers both with radio frequency or with audio frequency balance may be classed with this group. The fundamental difficulty of these methods is that two currents of unequal frequency can never cancel out each other, whereas two currents of the same frequency and magnitude and of opposite phase can so cancel out. This effect was demonstrated at the meeting by means of two oscillating valves which could be coupled to a third circuit containing a valve amplifier and loud speaking telephone. A promising improvement of these balanced aerial methods has recently been described ‡ in which a frequency changing coupling is used between the two aerial circuits so that the opposing currents may be given the same frequency. No test results of this arrangement are yet available. Weagant's spaced aerial receivers may also be included in this class.§

In the simplest of filtering circuits a negative resistance may be used to increase selectivity. This may be derived either from a valve with reaction coupling, or by the use of a special valve of the Pliodynatron type, or from a combination of valves as in Turner's Kallirotron.‖ The early patterns of Marconi X-stopper may be regarded as some of the earliest examples of true filtering circuits. More recently we have the Western Electric Co.'s filter circuits ¶ and Lévy's filter ** which is based upon the principle of the double heterodyne.

The properties of any given arrangement of receiving aerial are largely a question of its effective resistance to the incoming signals. Some arrangements of aerials give a larger ratio of signal strength to atmospheric strength than do others, and by combining two aerial systems having different values for this ratio it is possible to effect at least a partial elimination of the atmospherics. Typical examples described in the paper were Priess's and Pickard's circuits †† while finally A. H. Taylor's experiments on horizontal aerials were also detailed.‡‡

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* Abstract of paper read before the Wireless Society of London on May 21st, 1920.

† See RADIO REVIEW, I, pp. 317—329, April, 1920, for description.

‡ RADIO REVIEW Abstract No. 524. § RADIO REVIEW Abstract No. 18, October, 1919.

‖ RADIO REVIEW, I, pp. 317—329, April, 1920. ¶ RADIO REVIEW Abstract No. 523.

** RADIO REVIEW Abstract No. 196, February, 1920.

†† RADIO REVIEW Abstract No. 75, December, 1919, also Abstract No. 525.

‡‡ RADIO REVIEW Abstract No. 149, January, 1920, and No. 313, April, 1920.

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Review of Radio Literature.

1. Articles and Patents.

462. ON THE PERIOD AND DECREMENT OF AN OSCILLATORY ELECTRICAL CIRCUIT PROVIDED WITH A SHORT-CIRCUITED SECONDARY. I. Jones. (*Philosophical Magazine*, 39, pp. 553—565, May, 1920.)

The question of the influence of a short-circuited secondary is investigated mathematically commencing with the fundamental equations of the system. The complete formulæ for the frequency and decrement are not developed, but the results of particular solutions are given in the form of tables and curves. It appears from these that the expression

$$n = \frac{1}{2\pi}\sqrt{\frac{1}{C_1L_1} - k_1^2}$$

(where k_1 represents the decrement), which is strictly applicable to a single oscillatory circuit possessing resistance, cannot generally be used when the damping arises from the resistance of a closed secondary circuit. When the ratio R_2/L_2 of secondary resistance to secondary inductance is large the results found in the paper approximate to those given by the above formula. If secondary capacity is present the arrangement may possess two frequencies.

463. SPONTANEOUS ELECTRIC OSCILLATIONS IN VARIOUS CONDUCTORS. W. Schottky. (*Annalen der Physik*, 57, p. 541. *Elektrotechnische Zeitschrift*, 40, p. 526, October 16th, 1919. *Revue Générale de l'Électricité*, 7, pp. 84D—85D, March 13th, 1920, Abstract.)

Starting from the kT law (k = gas constant and T = absolute temperature) the author arrives at the conclusion that in a receiving circuit having a natural frequency within the audible limits the disturbance of electrons under the influence of heat should give rise to a continuous sound in a telephone connected to the end of the conductor, quite apart from any external influence, provided that the currents thus set up are sufficiently amplified. Similar oscillations due to the impact of an electrified particle on to the electrode of an amplifier are also referred to.

464. AN ARRANGEMENT FOR SETTING UP OSCILLATIONS OF A SINGLE FREQUENCY ONLY, E. Bellini. (*Revue Générale de l'Électricité*, 7, p. 117D—118D, April 10th, 1920. Abstract.)

See RADIO REVIEW Abstract No. 99.

465. INDUCTANCE, CAPACITY AND RESISTANCE OF COILS AT RADIO FREQUENCY. L. E. Whittemore and J. Breit. (*Revue Générale de l'Électricité*, 7, p. 83D—84D, March 13th, 1920, Abstract.)

See RADIO REVIEW Abstract No. 93 for the original paper.

466. CALCULATION OF ANTENNA CAPACITY. L. W. Austin. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 164—168, April, 1920. *Technical Review*, 6, p. 506, June 8th, 1920, Abstract.)

See RADIO REVIEW Abstract No. 88, January, 1920, where a paper has already been dealt with covering the same subject-matter.

467. ELECTRICAL MEASUREMENTS AT HIGH FREQUENCY. L. Brillouin. (*Bulletin de la Société Française des Électriciens*, 9, pp. 555—572, November, 1919. *Revue Générale de l'Électricité*, 7, p. 156, January 31st, 1920, Abstract. *Science Abstracts*, 23B, pp. 108—109, Abstract No. 203, February, 1920, Abstract.)

An account of methods developed mainly by Armagnat during the war. The resistance

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of frame aerials of various sizes, numbers of turns, spacings, etc., at various frequencies were measured by the added resistance method and also by the heating produced. The results agreed. A number of curves are given very similar to those given by Blatterman,* and the same expression is used as a measure of the efficiency of the coil as a receiver. Reference is made to the error in direction finding due to the direct aerial effect and unbalanced capacities. The calibration of wave meters by heterodyne methods is described and also various absolute methods, viz., by standardised coils and condensers, by high-frequency alternators and by the multivibrator of Abraham and Bloch. The various methods of tuning exactly to the harmonics of the latter are discussed.

468. ELECTRICAL MEASUREMENT. (*N. P. L. Review*, 1, pp. 29—30, January, 1920.)

A brief summary is given of the radio research work in hand at the National Physical Laboratory, this includes standardisation of high frequencies, investigation into the construction of loss-free mutual inductances and exploration of the characteristics of triode valves under different conditions of treatment and use.

469. THE MEASUREMENT OF VERY SMALL ALTERATIONS OF CAPACITY BY MEANS OF UNDAMPED OSCILLATIONS. J. Herweg. (*Verhandlungen der Deutschen Physikalischen Gesellschaft*, 21, pp. 572—577, September, 1919. *Science Abstracts*, 23A, p. 243, Abstract No. 619, April, 1920, Abstract.)

A heterodyne method in which the beat note from two generating triodes produces beats with the note from a standard fork. The alteration of the capacity of the oscillatory circuit of one generator is measured by the alteration in beat frequency. The whole of the apparatus with the exception of the telephone ear-piece and the tuning fork is enclosed in an earthed case. The method admits of the detection of a change of capacity of one part in a million.

470. MEASUREMENT OF RECEIVED RADIO CURRENTS WITH THE ELECTROMETER. E. O. Hulbert and G. Breit. (*Physical Review*, 15, pp. 405—408, May, 1920.)

In the method described a Dolezalek quadrant electrometer is connected across a resistance inserted in the plate circuit of a three-electrode valve which may be used alone as a detector, or as the detecting valve of a multi-stage amplifier. The vane of the electrometer is charged to 400 volts from a secondary battery. A sensitivity is obtained of 2,500 millimetres deflection per volt applied to the quadrant. The resistance in the plate circuit of the valve was from 20,000—60,000 ohms and a pair of telephone receivers was also included. To calibrate the arrangement a condenser potentiometer was arranged consisting of two variable condensers in series, across one of which the amplifier was joined. The electrometer deflection was found approximately proportional to the square of the mean value of the high frequency voltage impressed upon the amplifier.

471. SOME LABORATORY USES FOR THE CONTACT RECTIFIER. J. C. Jensen. (*Physical Review*, 15, pp. 224—225, March, 1920.)

In the experiments described a rectifier consisting of a piece of polished silicon pressed against polished carbon was found to give greater rectification and less resistance than a point contact. A pressure of about 5 grammes per square centimetre was used.

472. AN UNDAMPED WAVE METHOD OF DETERMINING DIELECTRIC CONSTANTS OF LIQUIDS. W. H. Hyslop and A. P. Carman. (*Physical Review*, 15, pp. 243—244, March, 1920.)

The measurements were made with two oscillating valve circuits using the beat method to indicate the frequency difference. The dielectric under test was introduced between the plates of a condenser forming part of one oscillation circuit, and the beat note restored to its original frequency by alteration of a standard condenser in parallel with the test condenser. Con-

* RADIO REVIEW Abstract No. 144.

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stancy of the beat note was obtained by comparison with a standard tuning fork For a wavelength of about 5,000 metres the following results were obtained at a temperature of 21° C. :—Kerosene 2·12, toluol 2·39, ether 4·32, olive oil 3·11, petrol-ether 1·86. Accuracy = 1 per cent.

473. CONDUCTIVITY AND DIELECTRIC COEFFICIENT OF DIELECTRICS AT HIGH FREQUENCIES. G. E. Bairsto. (*Proceedings of the Royal Society*, 96A, pp. 363—382, January 2nd, 1920. *Science Abstracts*, 23A, pp. 163—164, Abstract No. 433, March, 1920.)

Measurements of the A.C. conductivity, dielectric coefficient, and power factor of dry blotting paper, crown glass, vulcanised rubber, gutta-percha, marble and slate have been made at frequencies from 1,000 cycles to 3,000,000 cycles per second using an arc generator in compressed air to give oscillations of sinoidal wave-form. The hysteresis loss per cycle was found constant at low frequencies, while at very high frequencies it tended to vanish. The loss due to viscosity was found proportional to the square of the frequency at low frequencies. The maximum A.C. conductivity is very much greater than the D.C. conductivity. The dielectric coefficient increases rapidly at audio-frequencies but at a slower rate beyond the audio limit.

474. ELECTRO-PLATED IRON IN HIGH-FREQUENCY FIELDS. G. Preuner and L. Pungs. (*Verhandlungen der Deutschen Physikalischen Gesellschaft*, 21, pp. 594—602, September, 1919. *Science Abstracts*, 23A, p. 244, Abstract No. 622, April, 1920, Abstract.)

Experiments are described on the effect of giving iron fittings used in wireless installations an electrolytic deposit of copper or zinc. A deposit of from 0·03 to 0·04 mm. thickness was found sufficient to shield the iron so that the losses were nearly the same as if the fitting were of solid copper. The thickness of zinc should be of the order of 0·1 mm. for the same effect.

475. A POCKET SIZE WAVEMETER. E. Nesper. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 624—629, November, 1919. *Science Abstracts*, 23B, p. 172, Abstract No. 347, March, 1920, Abstract.)

The wavemeter described is contained in two boxes 20 × 10 × 7 cm. It comprises a circuit with a variable condenser of maximum capacity 1,200 cm., a hot wire instrument, and a set of five coils giving the following wavelength ranges : 45—220 m., 110—430 m., 270—1,150 m., 720—2,500 m., and 1,200—4,300 m. Photographs of the apparatus are given.

476. PRODUCTION OF UNDAMPED WAVES BY RHYTHMIC SPARKS. (*Génie Civil*, 76, p. 83, January 17th, 1920. *Revue Générale de l'Électricité*, 7, p. 103D, March 27th, 1920, Abstract.)

An illustrated description of the Marconi timed disc continuous wave oscillation generator—extracted from article in *Wireless World*, 7, pp. 310—316, September, 1919.

477. TRANSMITTERS. A. Taylor. (*French Patent* 498602, April 24th, 1919. Published January 16th, 1920.)

The invention relates to radiotelegraphic transmission systems and particularly to means for producing signals. The object is to provide a key capable of dealing with large currents.

For further particulars, see British Patent No. 131561.*

478. RADIOTELEGRAPHY. L. F. Fuller. (*U.S. Patent* 1330254, filed April 23rd, 1917. Patent granted, February 10th, 1920.)

This patent covers the same subject-matter as British Patent 133901.†

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* RADIO REVIEW Abstract No. 189.

† RADIO REVIEW Abstract No. 218 (March, 1920).

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479. APPARATUS FOR GENERATING UNDAMPED OSCILLATIONS. J. Nienhold. (*German Patent* 301241, April, 1917. Patent granted, October 9th, 1919. *Jahrbuch der Drahtlosen Telegraphie*, 15, p. 166, February, 1920, Abstract.)

A simple type of arc circuit with a cathode of an alkalic metal and a metallic anode (*e.g.* iron) both enclosed in an atmosphere of one of the inert gases.

480. FILTER CIRCUITS FOR HIGH FREQUENCY OSCILLATIONS. Western Electric Company, U.S.A. (*British Patent* 136712, February 19th, 1919. Patent accepted, December 24th, 1919.)

The object of the arrangement described is to provide a means for suppressing harmonics and allowing current of the desired frequency only to pass into the output circuit. The arrangement is indicated in Fig. 1 : V_1 is the

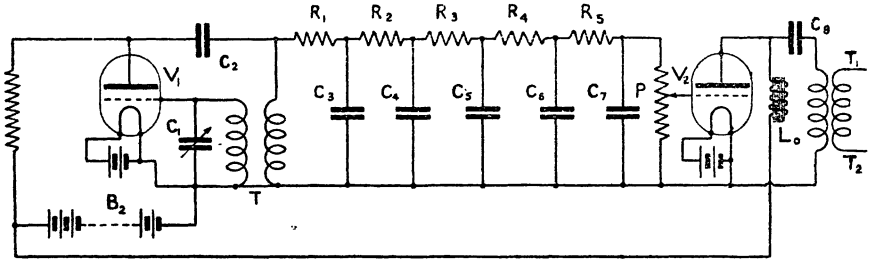

FIG. 1.

valve oscillation generator and V_2 is the valve amplifier. The output circuit is joined to T_1T_2. The resistances R_1 . . . R_5 are inserted between the condensers to prevent them from affecting the tuning of the circuits of the generating valve V_1. The capacity of these condensers C_3—C_7 are adjusted so as to offer a high impedance to the currents of the desired output frequency, but to allow the undesired harmonics to pass through them. The amplifier V_2 is fed from the potentiometer P as indicated. The condenser C_1 may alternatively be connected between the grid and anode of the oscillating valve, instead of in the position shown.

481. GENERATION OF OSCILLATIONS BY CATHODE-RAY VACUUM TUBES. E. F. Huth and S. Loewe. (*German Patent* 302465, July, 1917. Patent granted, October 4th, 1919. *Jahrbuch der Drahtlosen Telegraphie*, 15, p. 77, January, 1920, Abstract.)

A triode oscillator (see Fig. 2) with a single coil and variable condenser and filament tappings.

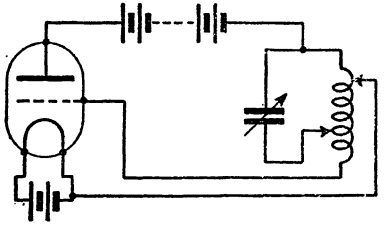

FIG. 2.

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482. METHODS OF USING TRIODES AS OSCILLATION GENERATORS. G. Vallauri. (*L'Elettrotecnica*, 7, pp. 60—62, February 5th, 1920.)

A non-mathematical discussion of several well-known methods. Suitable numerical values of L and C are given. A method is described in which the alternating current in the anode circuit of one valve acts on the grid of a second valve, thus amplifying the output. The use of an oscillating triode as a wavemeter, using the double click phenomenon, is also described.

483. SHAFT BEARINGS. E. F. W. Alexanderson. (*British Patent* 135824, October 17th, 1919. Convention date November 26th, 1918. Patent accepted, December 31st, 1919.)

Arrangements are described for equalising the thrust on two bearings placed at opposite ends of the shaft of an inductor alternator, by a special form of link mechanism connecting the two bearings.

484. HIGH FREQUENCY INDUCTOR ALTERNATORS. E. F. W. Alexanderson. (*British Patent* 135825, October 24th, 1919. Convention date, November 26th, 1918. Patent not yet accepted but open to inspection.)

This relates to the cooling of H.F. machines by pipes located in slots in the core rings and by appropriate shaping of the winding terminals, etc.

485. HIGH FREQUENCY INDUCTOR ALTERNATORS. E. F. W. Alexanderson. (*British Patent* 136147, October 27th, 1919. Convention date, December 6th, 1918. Patent not yet accepted but open to inspection.)

In the construction of the field magnet windings for high-frequency inductor alternators a number of independent exciting windings may be arranged so that each of them is capable of furnishing the full load field excitation. In the normal operation of the machine all the windings may be excited but in the event of the breakdown of one of the windings the remainder can be supplied with a larger current.

486. CHARACTERISTIC CURVES OF FREQUENCY DOUBLERS APPLIED TO RADIOTELEGRAPHIC TRANSMISSION. T. Minohara. (*Revue Générale de l'Électricité*, 7, pp. 283—291, February 28th, 1920. *Technical Review*, 6, p. 424, May 11th, 1920, Abstract. *Science Abstracts*, 23B, p. 202, Abstract No. 403, April 30th, 1920, Abstract.)

This paper investigates theoretically and experimentally the conditions of operation of frequency doublers (Joly-Vallauri type) in which two similar transformers are provided with both A.C. and D.C. magnetisation. Two conditions of operation are distinguished, (1) in which the secondary E.M.F. of double frequency is sinoidal with small power output, and (2) in which the secondary E.M.F. is rich in higher harmonics and has considerable power, while the second harmonic is filtered out by a resonant circuit. To obtain the first condition the A.C. ampere-turns must be 1·66 times the D.C. ampere-turns, and for the second case the two ampere-turns must be equal, while the D.C. excitation must bring the iron to the knee of the magnetisation curve. Maximum power is obtained when the secondary current is slightly leading. A number of oscillograms are included in the paper which support the theory.

487. RADIOPHONE MODULATOR. (*Wireless Age*, 7, p. 23, December, 1919.)

A number of microphones are arranged in series so that each one shunts only one or two turns of the aerial inductance. The microphones are all influenced by one mouthpiece.*

* See also RADIO REVIEW Abstract No. 131.

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488. IS RADIOTELEPHONY SUITABLE FOR INTERCOMMUNICATION IN LARGE ELECTRIC POWER SYSTEMS? J. Nübel. (*Elektrotechnische Zeitschrift*, 41, pp. 125—128, February 12th, 1920. *Technical Review*, 6, p. 341, April 13th, 1920, Abstract.)

A very thorough discussion of the relative merits of line and radio telephony in a large power distributing system, especially with overhead transmission. The author decides against radio telephony.

489. TELEPHONE TRANSMITTER. A. P. Pinkler. (*U.S. Patent* 1330391, filed March 2nd, 1917. Patent granted, February 10th, 1920.)

Relates to a special construction of microphone having a V-shaped insulating projection inside the granule chamber to restrict the current flow to the centre of the granular mass.

490. TELEPHONE RECEIVER. R. Nordenswan and R. C. Winckel. (*U.S. Patent* 1330214, filed January 4th, 1918. Patent granted, February 10th, 1920.)

Relates to a special construction of the magnet system for telephone receivers.

491. COMBINED TRANSMITTER AND RECEIVER FOR WIRELESS TELEPHONY. W. E. Barber. (*British Patent* 136654, December 20th, 1918. Patent accepted, December 22nd, 1919.)

The special feature described consists in the use of an electromagnetic relay for dimming the filaments of either the transmitting or receiving valves, the relay being controlled by speech currents from the transmitting microphone. The circuit arrangement is indicated in Fig. 3. The windings of the relay Y are inductively coupled through T_1 to the circuit of the transmitting micro-

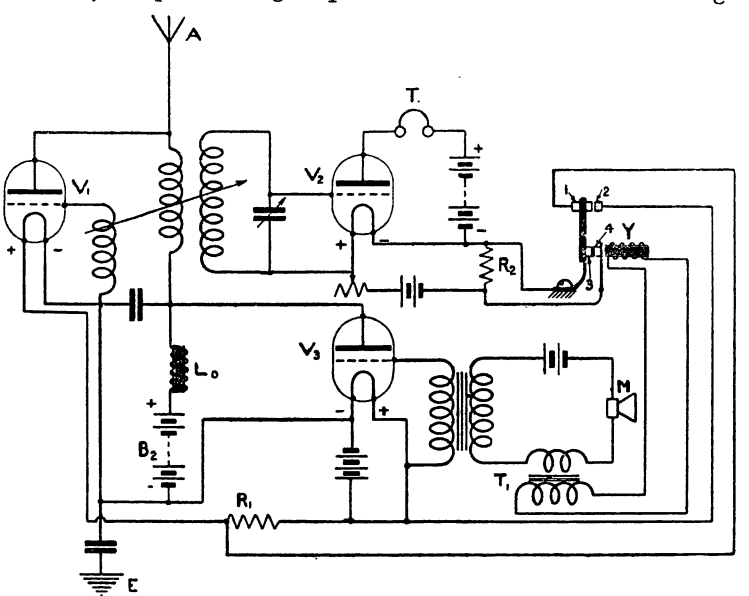

FIG. 3.

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phone M as indicated. Resistances R_1 and R_2 are joined in the filament circuits of the transmitting and receiving valves respectively. These resistances are short-circuited by the contacts 1, 2, and 3, 4 respectively, so that when current flows through the magnet windings of Y the resistance R_1 is short circuited while R_2 is not, and *vice-versâ*. The general arrangement of the transmitting circuit is the same as described in Major Prince's I.E.E. paper—see RADIO REVIEW, pp. 281—283, March, 1920.

492. DUPLEX WIRELESS SIGNALLING. P. P. Eckersley. (*British Patent* 135895, May 5th, 1919. Patent accepted December 11th, 1919.)

The proposed arrangement is indicated in Fig. 4. The transmitter G is included in the aerial circuit together with an inductance L_1 and a condenser C_1 which are made equal to the inductance and capacity of the aerial itself. A potential node is thus formed at the point P, and this point is earthed through the inductance L_2 and the condenser C_2 which are adjusted to tune the complete aerial circuit $AL_2C_2E_2$ to the frequency of the waves to be received. The inductance L_2 is coupled to the receiver through L_5. If the wavelengths of the transmitted and received waves differ less than 25 per cent., rejector circuits C_3L_3 and C_4L_4 tuned to the received and transmitted waves respectively may be inserted in the transmitting and receiving earth connections as indicated.

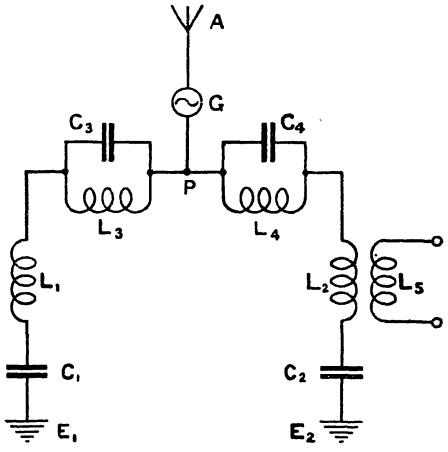

FIG. 4.

493. DUPLEX WIRELESS SIGNALLING. H. J. J. M. de R. de Bellescize. (*British Patent* 136524, July 5th, 1919. Convention date, December 7th, 1918. Patent not yet accepted but open to inspection.)

For duplex working using an ordinary open aerial for the transmitter, and a frame aerial for receiving, the transmitting aerial is arranged as symmetrically as possible about a plane passing through the transmitting aerial and at right angles to the plane of the receiving frame aerial. When the shape of the transmitting aerial cannot be modified to comply with this requirement the plane of the receiving frame aerial may be inclined to the vertical so as to reduce the interference to a minimum. In addition one or more small auxiliary frame aerials may be arranged near the receiving aerial and connected to it so as to still further reduce the disturbance from the transmitter. Various other compensating arrangements are also described in the original.

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494. TELEPHONE EARPIECES. E. Hausdorf. (*British Patent* 136511, September 9th, 1919. Patent accepted, December 18th, 1919.)

A telephone receiver for military and similar uses is provided with a double cover, the inner one being arranged to enter the ear and the outer one to embrace the ear. The arrangement is designed to exclude external noises.

495. WIRELESS SIGNALLING. Compagnie Française pour l'Exploitation des Procédés Thomson-Houston. (*French Patent* 499381, January 19th, 1918. Published February 10th, 1920.)

The invention described in this specification relates to wireless telegraphy systems, and more particularly a duplex system with provision for sending and receiving at a single station.

For further particulars, see British Patent No. 130090.*

496. TRANSATLANTIC RADIO COMMUNICATION. E. F. W. Alexanderson. (*Revue Générale de l'Électricité*, 7, p. 117D, April 10th, 1920, Abstract.)

See RADIO REVIEW Abstract No. 216.

497. VALVE CONSTRUCTION. V. J. F. Bouchardon and M. A. Lesage (*French Patent* 498736, April 29th, 1919. Published January 21st, 1920.)

The invention described in this specification relates to vacuum tubes having incandescent cathodes, such as valves. The object is to provide incandescent electrodes which will not readily break. For this purpose, the incandescent electrode comprises a round filament or a ribbon of tungsten, molybdenum or other difficultly fusible metal wound in a helix on a cylinder of refractory non-conducting material such as silica or porcelain.

498. PROTECTION DEVICE FOR VALVE FILAMENT. E. F. Huth. (*German Patent* 307682, March 3rd, 1918. Patent granted, October 1st, 1919. *Jahrbuch der Drahtlosen Telegraphie*, 15, p. 80, January, 1920, Abstract.)

A cathode consisting of two metal filaments of different resistances in parallel. Excessive heating of the filament which is used as the emitter makes its resistance greater than that of the other.

499. THE THEORY OF THE OSCILLATING AUDION. D. Coster. (*Physikalische Zeitschrift*, 20, pp. 579—584, December 15th, 1919. *Science Abstracts*, 23B, p. 224, Abstract No. 439, April, 1920, Abstract.)

The audion is treated as an A.C. generator with an internal resistance $\partial v_a/\partial i_a$ and an E.M.F. λv_g, where λ is the voltage ratio and v_g the alternating P.D. on the grid. To sustain undamped oscillations the conditions must satisfy an equation of the type $Ri + Ldi/dt + \frac{1}{C}\int idt = E\cos pt$, where E, which depends on v_g, is some function of I determined by the coupling between the anode and grid circuits. The equations are developed and solutions obtained for several methods of coupling.

500. THE ALGEBRA OF IONIC VALVES. W. H. Eccles. (*Technical Review*, 6, p. 226, March 2nd, 1920, Abstract.)

See RADIO REVIEW Abstract No. 421, June, 1920.

501. THERMIONIC VALVES. F. Bacon. (*Electrical Review*, 86, p. 661, May 21st, 1920, Abstract.)

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* RADIO REVIEW Abstract No. 202 (February, 1920).

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Paper read before the Institution of Electrical Engineers (Western Section).

A general distinction was drawn between two and three electrode valves, and the chief features of each described in a general way.

502. THE SELF-OSCILLATIONS OF A THERMIONIC VALVE. R. Whiddington. (*Proceedings of the Cambridge Philosophical Society*, 19, p. 346, February, 1920.)

Abstract of paper describing the phenomena dealt with by the same author in the RADIO REVIEW, 1, pp. 53—58, November, 1919. The formula for the frequency of the oscillations is given as $n^2 = (2e/md^2)V$, where n = frequency, e/m = ratio of charge to mass of the ion, d = radial distance from filament to grid, and V = the positive potential on the grid.

503. ON THE VARIATIONS OF WAVELENGTH OF THE OSCILLATIONS GENERATED BY THREE-ELECTRODE THERMIONIC TUBES DUE TO CHANGES IN FILAMENT CURRENT. W. H. Eccles and J. H. Vincent. (*Proceedings of the Royal Society*, 96A, pp. 455—465, February 3rd, 1920. *Nature*, 104, p. 617, February 5th, 1920, Abstract. *Science Abstracts*, 23B, pp. 223—224, Abstract No. 437, April, 1920, Abstract.)

The object of the investigations was to study experimentally the effects of altering the chief variables (filament current, plate and grid voltages, etc.) with a view to finding the most favourable conditions for the production of oscillations of constant frequency. Observations were made by means of the beat note produced between two circuits oscillating at nearly the same frequency, variations of this note being measured acoustically. At small filament currents the oscillation frequency decreased with increase of filament current, while at higher values it increased with the current. At a certain value of filament current the frequency was stationary for small variations of the current. Using this fact the frequency can be kept constant to 1 part in 100,000. Increasing the anode voltage increased the wavelength, as did also an increase of grid voltage.

504. A NEW LOW-POWER LAMP RECTIFIER OF ALTERNATING CURRENTS. J. Scott-Taggart. (*Electrician*, 84, p. 451, April 23rd, 1920. *l'Électricité*, 2, p. 12, June 1st, 1920, Abstract. *Science Abstracts*, 23B, p. 274, Abstract No. 540, May 31st, 1920, Abstract.)

A simple construction for a low-power low-voltage rectifier is described consisting of a flat nickel plate placed between the two legs of a horseshoe filament of spiralised tungsten wire. External connections are taken from the mid-point of the filament and from the plate. Alternate half-waves of the alternating voltage are rectified by the two halves of the filament. In an improved arrangement the complete V filament is surrounded by a cylindrical anode.

505. IMPROVEMENTS IN ELECTROMAGNETIC WAVE NAVIGATIONAL ARRANGEMENTS. J. Erskine-Murray and J. Robinson. (*British Patent* 135896, November 4th, 1919. Patent accepted, December 4th, 1919.)

A special form of "radiophare" is described. The transmitting station is provided with means of sending out signals in pairs in directions a definite azimuthal angle apart, the directions of propagation being gradually rotated. When the pairs of signals are of equal strength in the receiver, the line joining the stations bisects the azimuthal angle, and by noting the time or the number of signals that have passed since a definite cardinal point signal was heard, the direction of the transmitting station may be ascertained.

In one of the arrangements described a pair of crossed aerial coils or loops, arranged preferably at right angles to one another, are rotated about a

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central vertical axis. The exciting circuits are connected to the aerial in turn by a two-way switch so that a signal is sent out by each aerial in turn for every angular position of the pair.

Various other modifications are described using fixed aerial loops in conjunction with radiogoniometer coils.

506. APPARATUS FOR DETERMINING THE DIRECTION OF ARRIVING ELECTROMAGNETIC WAVES. J. Erskine-Murray and J. Robinson. (*British Patent* 136600, December 9th, 1918. Patent accepted December 9th, 1919.)

The arrangement described is apparently an attempt to obtain with one frame aerial the results obtainable with the well-known crossed coil R.A.F. arrangement. A pair of contacts are arranged on either side of the moving frame and a third contact on the frame itself may connect with either of the previously mentioned contacts. The circuit from the frame to the detector is made through either of these contacts so that a signal is heard when the frame is moved to touch either of the contacts, but is inaudible between them. The pair of contacts is mounted on two arms which may be rotated round the vertical axis of rotation of the receiving coil, and to determine the direction of an incoming wave the coil is oscillated from one contact to the other and the position of these contacts adjusted until the signal strengths obtained in the two positions are the same. The bisector of the angle between the contacts then indicates the direction of the incoming waves. A similar arrangement may be adapted to the moving coil of a radiogoniometer.

507. DIRECTION AND POSITION FINDING. H. J. Round. (*Journal of the Institution of Electrical Engineers*, 58, pp. 224—257, March, 1920. *Electrician*, 84, pp. 317—319, March 19th, 1920, Abstract. *Electrical Review*, 86, pp. 185—187, 220—221, February 6th and 13th, 1920, Abstract. *Engineering*, 109, pp. 108—112, January 23rd, and pp. 161—164, January 30th, 1920. *Science Abstracts*, 23B, pp. 218—220, Abstract No. 428, April, 1920.)

See RADIO REVIEW, 1, pp. 235—237 and 289—292, February and March, 1920, for abstract. Captain Round's reply is included in the *Journal of the Institution of Electrical Engineers*.

508. THE BEHAVIOUR OF HERTZIAN GRATINGS. R. Gans. (*Annalen der Physik*, 61, pp. 447—464, March 3rd, 1920, Abstract.)

A mathematical investigation of the action of a grating, consisting of a number of fine parallel wires, when placed in the path of an electromagnetic wave. The resistance of the wires is first neglected and then taken into account. Two cases are considered, viz., when the wires are in the plane of polarisation, and when they are at right-angles thereto. Previous work on the subject is criticised. The calculations are applied to experimental results obtained by Schaefer and Laugwitz, but the agreement is not good, one possible cause of the discrepancies being the use of damped oscillations in the experiments.

509. ON THE FUNDAMENTAL FORMULATIONS OF ELECTRODYNAMICS. G. H. Livens. (*Philosophical Transactions of the Royal Society*, 220A, pp. 207—245, March 17th, 1920. *Science Abstracts*, 23A, pp. 286—287, Abstract No. 738, May, 1920, Abstract.)

An attempt to formulate a complete statement of Maxwell's theory in a logically consistent form. This formulation is then compared with other statements of the theory. The fundamental equations are derived by using the principle of least action; the connections between the original differential theory and subsequent dynamical theories are discussed. The concluding section (15) contains a summary of the results of the discussion.

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510. THE SCATTERING OF PLANE ELECTRIC WAVES BY SPHERES. T. J. I'a Bromwich. (*Philosophical Transactions of the Royal Society*, 220A, pp. 175—206, February 2nd, 1920. *Science Abstracts*, 23A, p. 235, Abstract No. 601, April, 1920, Abstract.)

A mathematical paper giving results worked out some years ago. The author compares his methods and results with those of Rayleigh, Love, Nicholson and Macdonald.

511. THE NORMAL PROPAGATION OF E.M. WAVES THROUGH A LAYER OF VARIABLE DIELECTRIC CONSTANTS. J. Wallot. (*Annalen der Physik*, 60, pp. 734—762, December, 1919. *Science Abstracts*, 23A, p. 162, Abstract No. 430, March, 1920.)

A theoretical investigation of the partial reflection suffered by a plane wave when passing from one medium to another through a wall in which the dielectric constant changes gradually from that of the first to that of the second medium. The partial reflection is not appreciable unless the thickness is so small as to be comparable with the wavelength, but it increases as the thickness is decreased, reaching finally the value given by Fresnel's formula.

512. RECEPTION INTENSITY OF WIRELESS WAVES. A. Press. (*Electrician*, 83, p. 629, December 5th, 1919. *Revue Générale de l'Électricité*, 7, p. 83D, March 13th, 1920, Abstract. *Science Abstracts*, 23B, p. 167, Abstract No. 337, March, 1920, Abstract.)

This paper is in the nature of a preliminary note to a contribution which is to appear in the *Proceedings of the Institute of Radio Engineers*. The author distinguishes two sets of waves sent out from a vertical grounded antenna, (1) designated as "galvanic" radiation and set up by the magnetic linkings, and (2) designated as "voltaic" radiation, and set up by the electrostatic effect of the antenna. Equations are deduced for each of these components and their form is found to correspond with that of an empirical formula given by W. H. Eccles in his "WIRELESS TELEGRAPHY AND TELEPHONY."* One of the coefficients also suggests the type of correction factor put forward by Dr. Cohen.†

513. ON THE PROPAGATION OF ELECTROMAGNETIC WAVES AROUND THE EARTH. B. van der Pol. *Revue Générale de l'Électricité*, 7, p. 98, March 27th, 1920, Abstract.)

See RADIO REVIEW Abstract No. 48, November, 1919.

514. RECORDING JAVA RADIO SIGNALS IN GERMANY. (*Elektrotechnische Zeitschrift*, 41, p. 141, February 12th, 1920.)

The signals received at Geltow (near Berlin) on a frame aerial 80 metres square from Malabar (arc) and Tjililin (alternator and frequency transformers) are recorded as dots and dashes on a tape. The antenna power in each case is 80 kw.

515. REVERSIBLE OR RECIPROCAL AMPLIFIERS. M. Latour. (*Bulletin de la Société Française des Électriciens*, 9, pp. 589—600, December, 1919. *Revue Générale de l'Électricité*, 7, pp. 359—364, March 13th, 1920, Abstract. *Technical Review*, 6, p. 424, May 11th, 1920, Abstract. *Science Abstracts*, 23B, p. 280, Abstract No. 552, May 31st, 1920, Abstract.)

Transformer windings and connections whereby a three-electrode valve inserted in a telephone line acts as an amplifier to speech in either direction.

516. THE DESIGN OF MULTI-STAGE VACUUM-TUBE RECEIVING CIRCUITS. J. Scott-Taggart. (*Wireless Age*, 7, pp. 15—17, December, 1919.)

This article describes the arrangement of a three-valve amplifier with aperiodic inductance coupling and a four-stage amplifier with tuned inter-valve auto-transformer coupling.

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* (London: *Benn Bros., Ltd.* Second Edition, 1918, p. 153.)

† See *Electrician*, 86, pp. 743—744, February 25th, 1916.

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517. VACUUM TUBE AMPLIFYING CIRCUIT. E. F. Huth and L. Kühn. (*German Patent* 307681, November 21st, 1917. Patent granted, October 6th, 1919. *Jahrbuch der Drahtlosen Telegraphie*, 15, p. 78, January, 1920, Abstract.)

A two-valve amplifying circuit (see Fig. 5) in which retroaction in one valve circuit is brought about by an intermediary valve V_2.

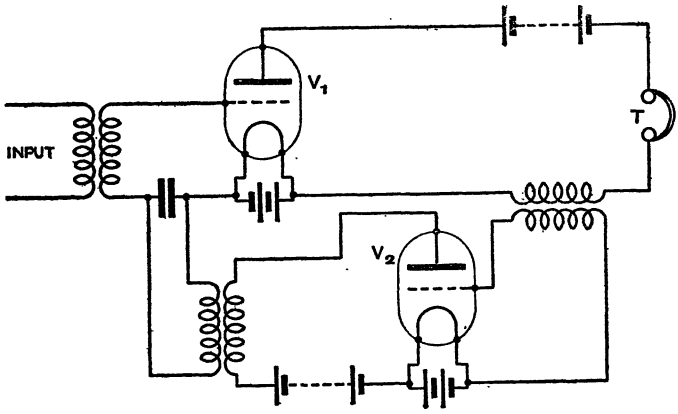

FIG. 5.

518. A MEDIUM-WAVE REGENERATIVE RECEIVER. E. G. Underwood. (*Wireless Age*, 7, pp. 25—26, December, 1919.)

The article includes constructional details and illustrations of the receiver.

519. AMPLIFIER DETECTOR FOR WIRELESS TELEPHONY. L. N. Brillouin and G. A. Beauvais. *Revue Générale de l'Électricité*, 7, p. 118D, April 10th, 1920, Abstract.)

See RADIO REVIEW Abstract No. 153.

520. NOTES ON BEAT RECEPTION. L. W. Austin and F. G. Grimes. (*Journal of the Washington Academy of Sciences*, 10, pp. 174—177, March 19th, 1920. *Science Abstracts*, 23B, p. 275, May, 1920, Abstract.)

The paper briefly summarises the results of experiments on the various factors influencing heterodyne and autodyne reception. For any given circuit, valve, and wavelength, best results were obtained with the same strength of heterodyne oscillations, independent of the signal strength. The linear response relation previously found for the autodyne was found to also hold for separate heterodyne with either triode or crystal detector. Large resistances may be inserted in the receiver secondary circuit without impairing signal strength, provided local oscillations are kept at the same strength. Hence with an oscillating tube directly in a loop circuit the received signal strength is independent of the loop resistance. The sensitiveness was found to be independent of the ratio L/C, provided local oscillations were kept at best value. The de-tuning of the receiver with autodyne reception was found not to reduce its sensitiveness as compared with heterodyne if a sensitising circuit was coupled to the secondary circuit so that the coupling wavelengths agree with the signal and heterodyne wavelengths, but the separate heterodyne was less liable to interference.

521. MUSICAL RECEPTION WITH CONTINUOUS WAVES WITHOUT LOCAL OSCILLATIONS. L. W. Austin. (*Journal of the Washington Academy of Sciences*, 10, pp. 223—226, April 19th, 1920.)

Some experiments on a "tone wheel" detector are described with a view to comparing its

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sensitiveness with that of a heterodyne receiver. The chief results were as follows :—The sensitiveness of the tone wheel without amplification varies from one-sixth to one-third of that of the oscillating triode; the law of response is linear. The tone wheel is somewhat superior to the heterodyne in keeping out strong interference; it may be used either with radio or audio frequency amplifiers, the former being preferable. The brush action is improved by filling in the spaces between the teeth with insulating material.

522. AMPLIFICATION OF CURRENT IN A BUNSEN FLAME. C. W. Heaps. (*Physical Review*, 15, pp. 222—223, March, 1920.)

Experiments are described designed to ascertain whether a similar effect could be obtained with a third terminal or grid in a Bunsen flame as in a triode valve. The characteristic curves obtained were very similar to the usual valve curves. The best arrangement of electrodes in the flame consisted of (1) a clean horizontal platinum wire near the base of the flame to act as the "plate"; (2) a horizontal wire with about a centimetre of the end bent upwards to serve as cathode; and (3) a coil of three or four turns of wire serving as a "grid" and placed over the upturned end of the cathode. On the tip of the cathode a little sealing wax was burnt to leave a residue which when heated acted as an efficient source of electrons. The energy amplification was of the order of 450 to 500.

523. IMPROVED CIRCUIT ARRANGEMENTS FOR THE REDUCTION OF STATIC INTERFERENCE IN RADIO RECEIVING STATIONS. Western Electric Company, U.S.A. (*British Patent* 135635, December 6th, 1918. Patent accepted, December 4th, 1919.)

This patent describes a number of special filter circuits designed with the object of allowing certain frequencies to pass and cutting out others. In particular two types are mentioned: infra-filters which operate to suppress currents of a frequency below a certain limit, and ultra-filters for suppressing currents of a frequency above a certain limit. By a combination of the two types of filter only currents between the two frequency limits are transmitted. The simplest form of the filter arrangement is indicated in Fig. 6 (a) and

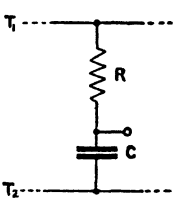

FIG. 6 (a).

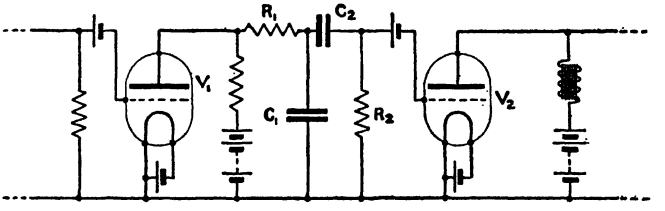

FIG. 6 (b).

consists of a resistance R in series with the condenser C. The input circuit is connected to T_1 and T_2, and if the output circuit is joined across the terminals of the condenser C currents of lower frequency only will predominate in the output circuit, since the ratio of the voltages across the capacity and across the resistance will be greater the lower the frequency. By connecting the output circuit across the resistance R the device operates as an infra-filter. Alternatively the condenser may be replaced by an inductance but this results in an inversion of the frequencies transmitted in the two cases.

When using a number of such filters thermionic valve amplifiers may be connected between successive filters to prevent reaction of the output circuit

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on to the input circuit. For minimising atmospheric disturbances in wireless reception the aerial is arranged to be out of tune with the signal wave and is connected to the detector through a series of filters of both types. These should be adjusted so as to transmit most efficiently a narrow band of frequencies in the neighbourhood of the signalling frequency. Fig. 6 (b) indicates another combination of an ultra-filter composed of a series resistance R_1 and a shunt capacity C_1 with an infra-filter composed of a series capacity C_2 and a shunt resistance R_2 for the purpose of transmitting only such a band of frequencies.

524. RADIO-FREQUENCY INTERFERENCE BALANCE. (*Wireless Age*, 7, pp. 21—23, December, 1919.)

The arrangement described is an attempt to overcome the disadvantages of the use of two aerials, one tuned to the signal and the other de-tuned and both coupled to the receiving detector for the elimination of atmospherics. In this case the coupling between the two aerial systems is provided by a frequency converter of the Goldschmidt type with its rotor circuit arranged to generate at frequency n. One aerial circuit is tuned to the signal frequency N and the other de-tuned to the frequency N_1. The frequency n is chosen so that $N - n = N_1 + n$ and the detector circuit is tuned to this intermediate frequency $N - n$. By this means the impulses due to atmospherics may be cancelled out and the signal received on one aerial only.

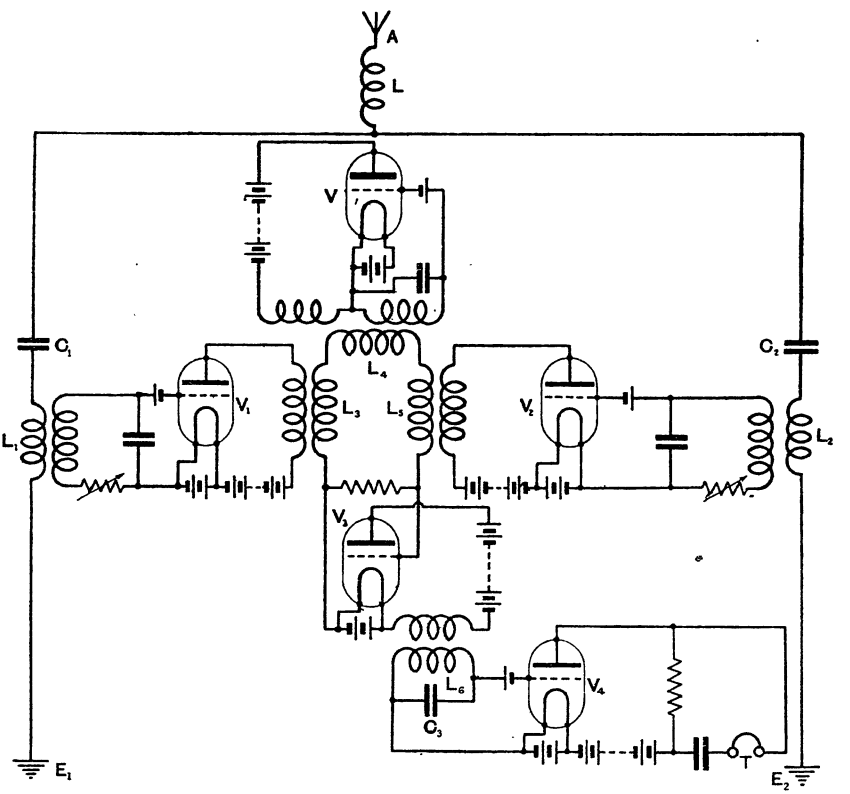

FIG. 7.

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In a modification a single aerial with two branches tuned to the two frequencies N and N_1 may be used in conjunction with a valve arranged to generate oscillations of frequency n. The circuit diagram is indicated in Fig. 7 in which the branch C_1L_1 is tuned to the signal frequency N and C_2L_2 to the frequency N_1. The valve V generates the frequency n. V_1 V_2 and V_3 are high frequency amplifiers, and the circuit $L_3L_4L_5$ is connected so that the currents of frequency $N - n$ from V_1 cancel out those of frequency $N_1 + n$ from V_2. The circuit L_6C_3 is tuned to the frequency $N - n$. V_4 is the detecting valve.

525. STATIC ELIMINATION BY DIRECTIONAL RECEPTION. G. W. Pickard. (*Radio Amateur News*, 1, pp. 337—341, January, 1920.)

Paper read before the Institute of Radio Engineers. It opens with a summary of the various theories that have been proposed to account for the different varieties of atmospherics. A number of experiments carried out by the author are also detailed together with quotations from various American papers and other publications describing various forms of directional receivers particularly adapted to reducing static interference. The receiver using the combined loop and open antenna effects, described in RADIO REVIEW Abstract No. 75, December, 1919, Fig. 6, p. 152, is also described, together with various modifications of it. One of these is indicated in Fig. 8. The loop L was a rectangle of solenoidal form 30 metres long by 6

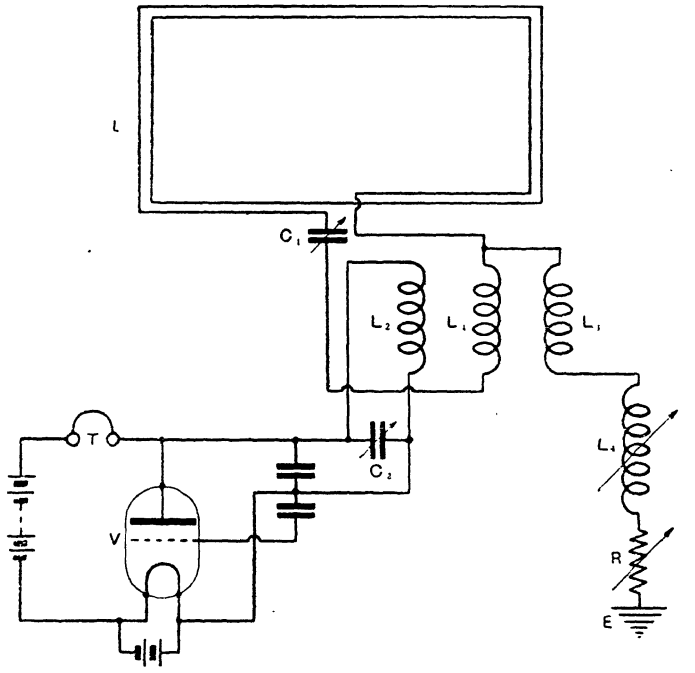

FIG. 8.

metres high, with its lower side 4 metres from the ground and having 4 turns spaced 30 cm. apart. It is tuned by the variable condenser C_1 and coupling coil L_1. The whole loop acting as an open antenna to the ground is tuned by the inductance L_4. The resistance R is necessary to equalise the currents in the two coils L_1 and L_3 and its value is usually about 3,000 ohms. L_1 and L_3 are closely coupled and L_1 and L_2 more loosely coupled. The circuit L_2C_2 in conjunction with the valve V forms the usual receiver. A slight improvement may be obtained by arranging the earth lead from R to E in the form of an additional loop of wire placed

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parallel with and close to the main loop L. A further improvement is indicated in Fig. 9 and in this case no direct earth connection is made to the loop circuit but the open antenna A earthed through L_3C_3R is used with the earth connection. The coil L is of the same type

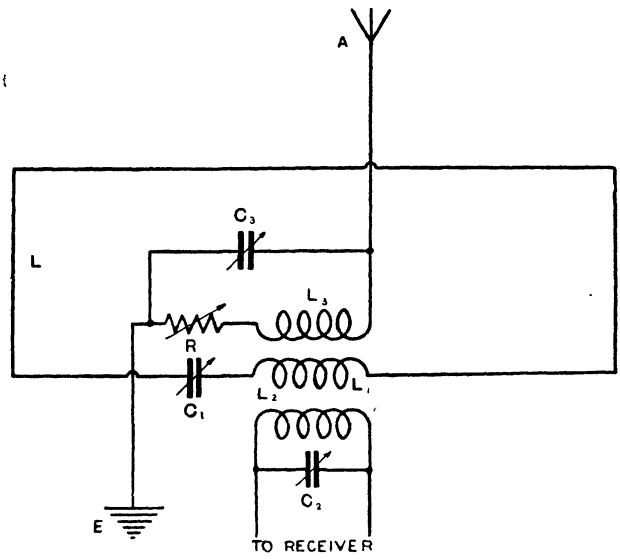

FIG. 9.

as in the previous example. This arrangement was said to enable transatlantic messages to be copied continuously through the heaviest static. Still another arrangement giving good results is indicated in Fig. 10. In this case two horizontal aerials A_1 and A_2 are used and no

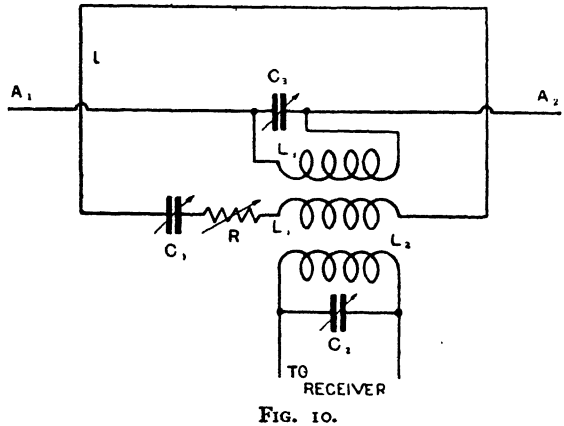

FIG. 10.

earth connection. The resistance R in this case of about 1,000 ohms is also used as before to equalise the currents in the two circuits.

An interesting point mentioned in the paper is that on the northern Atlantic seaboard of the U.S. the predominant static arrived from the western or south-western horizon. This effect vanished a short distance inland.

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526. WIRELESS SIGNALS. Compagnie Française pour l'Exploitation des Procédés Thomson-Houston. (*French Patent* 499212, May 8th, 1919. Published February 4th, 1920.)

This specification describes a system of radio-signalling, and more particularly a system in which means are provided for overcoming the effect of static disturbances in the receiving instruments.

For further particulars of this invention, see British Patent No. 134585.*

527. PORTABLE WIRELESS RECEIVING APPARATUS. R. C. Clinker. (*British Patent* 135932, December 3rd, 1918. Patent accepted, December, 3rd, 1919.)

The portable apparatus covered by this specification is that described on pp. 292—293, of the RADIO REVIEW (March, 1920).

528. AERIAL CONSTRUCTION. Marconi's Wireless Telegraph Co., Ltd. (*French Patent* 498940, March 23rd, 1917. Published January 27th, 1920.)

The invention described in this specification relates to directive propagation and reception of wireless signals. For this purpose the transmitting or receiving antenna is placed in the focus of a row of aerials arranged in a parabola, all of which are tuned to the wavelength employed by means of adjustable capacities or inductances. The auxiliary aerials act as reflectors and may be earthed or not. The aperture of the parabolic row should not be less than the wavelength employed and the distance between the aerials may be one-tenth of their height, the focal distance of the parabola being preferably, 1, 3, 5, etc., quarters of the wavelength.

For further particulars of this invention, see British Patent No. 105909.

529. DEVELOPMENT OF LOOP AERIAL FOR SUBMARINE RADIO COMMUNICATION. J. A. Willoughby and P. D. Lowell. (*Revue Générale de l'Électricité*, 7, p. 84D, March 13th, 1920, Abstract.)

See RADIO REVIEW Abstract No. 85.

530. THE PRIESS LOOP SETS. W. J. Henry. (*Radio Amateur News*, 1, p. 270, December, 1919.)

This article briefly describes the development of portable loop aerial transmitters and receivers for use in trench warfare and operating on wavelengths between 66 and 180 metres. Damped wave transmission was used throughout. Reliable communication was established between two of these sets in dug-outs separated by 6 km. using 30 watts at the transmitter. The complete set weighed 28 lbs. including the loop aerial, tools and spare parts.

531. THE WIRELESS STATION AT NAUEN: (1) THE DEVELOPMENT. Count G. Arco. (*Elektrotechnische Zeitschrift*, 40, pp. 665—667, December 18th, 1919. *Science Abstracts*, 23B, pp. 215—217, Abstract No. 426, April, 1920, Abstract.)

A brief sketch of the development of the Nauen Station from 1906 to the present day.

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* RADIO REVIEW Abstract No. 371 (May, 1920).

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532. THE WIRELESS STATION AT NAUEN: (2) THE HIGH FREQUENCY ALTERNATOR AND TRANSFORMERS. W. Dornig. (*Elektrotechnische Zeitschrift*, 40, pp. 687—689, December 25th, 1919. *Science Abstracts*, 23B, pp. 215—217, Abstract No. 426, April, 1920, Abstract.)

There are two aerials the larger a T aerial over 2 km. long with a capacity of 30,000 cm. and the smaller a triangular aerial of 15,000 cm. The former is supplied from the 400-kW. high-frequency machine and the latter from the 100-kW. quenched spark set. Details and a photograph of the 400-kW. machine are given. The 7-ton cast steel inductor of 1·65 metre diameter runs at 1,500 r.p.m. and having 240 teeth gives a frequency of 6,000. The rotor carries two ventilators and water-cooling tubes run through the armature stampings behind the winding tunnels. The output is 1,200 amperes at 450 volts. This passes through a step-up transformer and then through two or three frequency-doubling transformers in cascade. The Morse key causes a relay to short-circuit a resistance inserted between the step-up transformer and the first doubler. A somewhat detailed description is given of the 400-kW. frequency-doubler for $f = 12{,}000/24{,}000$. The stampings are 0·07 mm. thick but only weigh 26 kg., whilst the weight of copper is only 20 kg. Two such transformers constitute the doubler. They are oil immersed and also have forced oil circulation with external oil cooling. The motor input is 620 kW. on a long dash and 325 kW. when sending. The power supplied to the antenna is 410 kW.

533. GERMAN RADIO WAR INSTRUMENTS. (*Radio Amateur News*, 1, p. 271, December, 1919.)

Illustrated descriptions of a two-valve amplifier, crystal detector and high note buzzer.

534. RADIO COMMUNICATION BETWEEN GERMANY AND AMERICA, SPAIN AND SWEDEN. (*Elektrotechnische Zeitschrift*, 41, pp. 121—122, February 5th, 1920.)

Nauen is now in regular communication with Annapolis and New Brunswick and telegrams should be marked "Cable" or "Radio"; the rate is the same. Many of the cables are still unrepaired, the Entente having taken the German cable ships. Telegrams for Sweden are transmitted from Konigswusterhausen to Carlsborg and those for Spain from Eilvese to Madrid and Aranjuez.

535. THE ANNAPOLIS RADIO STATION. (*Wireless Age*, 7, pp. 10—15, December, 1919. *Science Abstracts*, 23B, pp. 217—218, Abstract No. 427, April, 1920, Abstract.)

A general description with illustrations and circuit diagrams of the Annapolis (NSS) radio station with views of the 350 kW. arc apparatus.

536. THE KAMINA WIRELESS STATION, ITS CONSTRUCTION AND DESTRUCTION. (*Wireless World*, 7, pp. 491—495, December, 1919.)

An illustrated description of the capture of the station by the British.*

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* See also RADIO REVIEW Abstract No. 537.

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537. DESTRUCTION OF THE GERMAN WIRELESS STATION AT KAMINA IN TOGOLAND. M. Roscher. (*Elektrotechnische Zeitschrift*, 41, p. 116, February 5th, 1920.)

The author had erected and was in charge of the station, which was utterly destroyed by his orders on the approach of the British. He criticises sharply the references to this event in the *Wireless World*.* His description of the destruction by those who had watched over the growth of the station and had great hopes of its achievements is very touching, but the article is marred by a spirit of bitter animosity.

538. THE RADIO TELEGRAPHIC STATION AT ROME (SAN PAULO). B. Micchiardi, G. Pession and G. Vallauri. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 142—163, April, 1920. *Technical Review*, 6, p. 506, June 8th, 1920, Abstract.)

Describes in detail the high power arc station erected by the personnel of the Royal Italian Navy for the Italian Government during the months May—October, 1917. The station was designed to communicate with the Italian colonies on the Red Sea and also with the American high-power stations. The antenna has the form of an equilateral triangle supported by three cables (spreaders) more than 610 feet in height with the down leads coming from one of the sides. It is supported on wooden masts having a triangular lattice-work structure. The set is, like most of the Naval sets, of the Poulsen arc type being provided with a rectangular magnetic circuit with an air gap of 8·2 cm. giving a field intensity of 6,700 gauss with a supply current of 220 amperes.

Normal operation of the station is carried out on a wavelength of 11,000 metres signalling being accomplished by short circuiting a number of turns of the antenna inductance. The "working" and "stand-by" waves are thus made to differ by 180 metres. Experiments are in progress on methods of eliminating the "stand-by" wave by the use of an artificial absorbing antenna circuit.

By measuring the current absorbed at resonance in an experimental loop antenna at Fiumicino when the station of San Paulo was transmitting the effective height of the aerial at the latter has been shown to be 462 feet on wavelengths between 6,800 and 10,000 metres.

Two small receiving stations are worked in conjunction with the transmitter. One station adjoins the transmitting station and is lined with metallic netting to protect the receiver from excessive induction. The other which possesses a loop antenna permits of duplex working with America. Detailed data of reception with American stations are given.

539. COMPLETION OF THE WIRELESS INLAND NETWORK BY THE FUNK-BETRIEBSAMT. V. T. D. Thurn. (*Telegraphen- und Fernsprech-Technik*, 8, pp. 121—124, November, 1919, Abstract.)

The German Government have appointed the Funk-Betriebsamt to control the installation and operation of a network of wireless telegraphic stations throughout the country. Small stations communicate with their district stations and these district stations can communicate with Berlin. For reasons of economy, army and navy apparatus is being utilised for the purpose, the standard system being a continuous wave one with thermionic valve generators and beat reception. The organisation is very fully described in this article which is officially communicated.

540. THE CONSTRUCTION OF A RADIO-FREQUENCY TRANSFORMER. (*Everyday Engineering Magazine*, 8, pp. 310—312, February, 1920.)

Constructional details with dimensioned drawings are given for iron cored radio-frequency inter-valve transformers for use in a high-frequency multi-stage valve amplifier.

541. CONSTRUCTIONAL DETAILS OF THE DOUBLE CONDENSER. (*Everyday Engineering Magazine*, 8, pp. 114—115, November, 1919.)

The condenser described has a double set of fixed and moving vanes, each

* RADIO REVIEW Abstract No. 536.

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set of fixed vanes being connected to one set of moving vanes. Double the capacity is thus obtained without increasing the size of the instrument.

542. THE DESIGN OF CONTACTS AND SOCKETS FOR WIRELESS VALVES OR VACUUM TUBES. W. J. Polyblank. (*British Patent* 135792, June 13th, 1919. Patent accepted, December 4th, 1919.)

Constructional details are given for the base and contact pins of triode valves.

543. DATA ON THE INTERNATIONAL RADIO OSCILLATION TRANSFORMER. (*Everyday Engineering Magazine*, 8, p. 117, November, 1919.)

Wavelength curves of apparatus manufactured by the International Radio Co. (U.S.A.).

544. WIRELESS RECEIVING APPARATUS AT GELTOW (POTSDAM). (*Elektrotechnische Zeitschrift*, 41, pp. 41—42, January 8th, 1920. *Telefunken Zeitung*, Nos. 17 and 18, January, 1920.)

In order to work duplex at Nauen, the receiving station has been placed at Geltow, 30 km. away. A description is given of the frame aerial 28 metres square with 6 turns, tuned, and coupled to a secondary tuned circuit which is connected through a cascade amplifier to the detector, and then through a low frequency amplifier, an acoustic resonance transformer and a rectifying tube to the inker, which is capable of working at 100 words per minute. Although 30 km. away they cannot work within the range 10 per cent. above and below the wavelength emitted by Nauen. They receive satisfactorily, however, both New Brunswick ($\lambda = 13{,}500$ m.) and Annapolis ($\lambda = 17{,}000$ m.) simultaneously on two frames 1 metre apart.

545. SOME RECENT DEVELOPMENTS IN RADIO TRANSMITTERS. M. W. Sterns. (*Wireless Age*, 7, pp. 17—20, December, 1919.)

Describes the direct current buzzer transmitters manufactured by The Sperry Gyroscope Company. They consist of a vibrating contact which interrupts the current from the source at about 400 volts. Across the contacts is shunted a capacity-inductance circuit coupled to the aerial. The article is accompanied by several illustrations of the sets. Transmission power is up to 200 watts.

546. THE VIBRATORY CONVERTER AS AN A.C. GENERATOR FOR SMALL RADIOTELEGRAPH STATIONS. F. Falkenthal. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 526—534, October, 1919. *Science Abstracts*, 23B, p. 162, Abstract No. 326, March, 1920, Abstract.)

The article describes the application for low-power radio transmission of vibratory apparatus normally used for rectifying A.C. With a primary energy of 250 watts, 80 per cent. efficiency of conversion is obtained. Heavy contact pressure was necessary to avoid loss of energy. Sparking rates of 400 to 600 per second were obtained. It was necessary to maintain the armature continuously in vibration in order to ensure resonance with the low frequency circuits necessary to prevent sparking. Signalling was effected by short-circuiting a resistance in the primary circuit.

547. CHARACTERISTICS OF MICA TRANSMITTING CONDENSERS. L. R. Jewett. (*Radio Amateur News*, 1, pp. 272—273, December, 1919.)

An illustrated description of the construction of 0·004 microfarad units of mica transmitting condensers enclosed in aluminium cases. A very low power-factor, small losses, compactness and high efficiency are the chief features.

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548. ELECTRIC CONDENSERS. W. Dubilier. (*British Patents* 140045 and 140046, July 24th, 1919. Patents not yet accepted but open to inspection.)

Special methods of construction of multi-section condensers are detailed. The arrangement is particularly suitable for high-voltage condensers comprising a number of sections connected in series and subjected to mechanical compression. This compression may be provided by suitable clamping bolts and plates, or the condenser sections may be clamped between the sides of the metallic containing case which then forms one terminal of the complete condenser.

549. CONDENSERS. W. Dubilier. (*French Patent* 498639, April 25th, 1919. Published January 16th, 1920.)

This specification describes a high potential condenser suitable for use in wireless telegraphy. For further particulars, see British Patent No. 140046.*

550. A NEW TYPE OF NON-INDUCTIVE RESISTANCE. H. L. Dodge. (*Physical Review*, 15, pp. 223—224, March, 1920.)

A special arrangement of winding is detailed so that every part of the conductor is closely adjacent to a similar part carrying current in the opposite direction. Self-capacity is small.

551. NEW MARCONI WIRELESS CALL SIGNAL DEVICE. (*Shipbuilding and Shipping Record*, 15, pp. 108—109, January 22nd, 1920. *Technical Review*, 6, p. 226, March 2nd, 1920, and p. 342, April 13th, 1920, Abstract. *Wireless World*, 7, pp. 695—698, March, 1920. *Telegraph and Telephone Age*, 38, p. 149, March 1st, 1920. *L'Électricien*, 50, p. 157, April 15th, 1920.)

See also RADIO REVIEW, 1, p. 293, March, 1920. (*Note.*—The complete illustrated description is given in *Wireless World*—above reference.)

552. THE APPLICATION OF ULTRA VIOLET RAYS TO SIGNALLING. I. G. Priest and K. S. Gibson. (*Revue Générale de l'Électricité*, 7, p. 75D, March 6th, 1920, Abstract.)

553. THE DETECTION OF INVISIBLE BODIES BY MEANS OF INFRA RED RAYS. S. O. Hoffman. (*Revue Générale de l'Électricité*, 7, p. 75D, March 6th, 1920, Abstract.)

554. THE UTILISATION OF INFRA RED AND ULTRA VIOLET RADIATIONS DURING THE WAR. (*Illuminating Engineer*, 12, pp. 295—296, October, 1919. *Revue Générale de l'Électricité*, 7, p. 98D, March 27th, 1920, Abstract. *Telegraphen- und Fernsprech-Technik*, 8, pp. 112—113, October, 1919. *Elektrotechnik und Machinenbau*, 38, p. 34, January 18th, 1920. *Technical Review*, 6, p. 425, May 11th, 1920, Abstract.)

See also RADIO REVIEW Abstract No. 71, November, 1919.

555. ON THE RELATION BETWEEN ILLUMINATION AND ELECTRICAL CONDUCTIVITY IN SELENIUM. A. O. Rankine. (*Philosophical Magazine*, 39, pp. 482—488, May, 1920.)

Experiments are described proving that the change of conductivity of selenium cells is proportional to the fourth root of the intensity of illumination, and not to the square root as usually assumed.

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* RADIO REVIEW Abstract No. 548.

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556. A SECRET TELEPHONE. P. Maurer. (*L'Électricien*, 50, pp. 199—201, May 15th, 1920.)

For the purposes of secret telephony for wartime use along badly insulated wires, a small radiotelephone transmitter was employed coupled between the line and earth. An oscillating valve was used with the transmitting microphone coupled to the oscillation circuit.

557. A TELEPHONE TO EUROPE? C. H. Claudy. (*Scientific American*, 122, p. 513, May 8th, 1920.)

A *resumé* of experiments on the use of radio frequency currents for the transmission of telephone or telegraph signals along bare wires laid in sea water.

558. THE ELECTRICAL EQUIPMENT OF AIRCRAFT. P. Maurer. (*L'Électricien*, 35, pp. 265—269, December, 1919.)

Deals amongst other matters with generators, etc., for use with the wireless installation.

559. NAVAL AIRCRAFT RADIO. T. Johnson, Jr. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 87—141, April, 1920. *Technical Review*, 6, p. 466, May 25th, 1920; and p. 506, June 8th, 1920, Abstract.)

Constitutes the second half of the author's paper in the same Proceedings of February, 1920.* The development of the earlier types of radio sets used on American Naval Aircraft is described. The standard transmitting sets, of which full details (dimensions, circuits, ranges, etc.) are given, were practically all developed by the Western Electric Company and may all be regarded as modifications of the fundamental circuit shown in Fig. 11, which provides for transmission by unmodulated, buzzer-modulated, or telephonic-modulated continuous waves.

Power is supplied for the set by the battery B which supplies current both for the filaments and the dynamotor D. The latter supplies a high tension to the anode circuits. Modulation of the radio frequency energy is effected by imposing the audio-frequency output of the

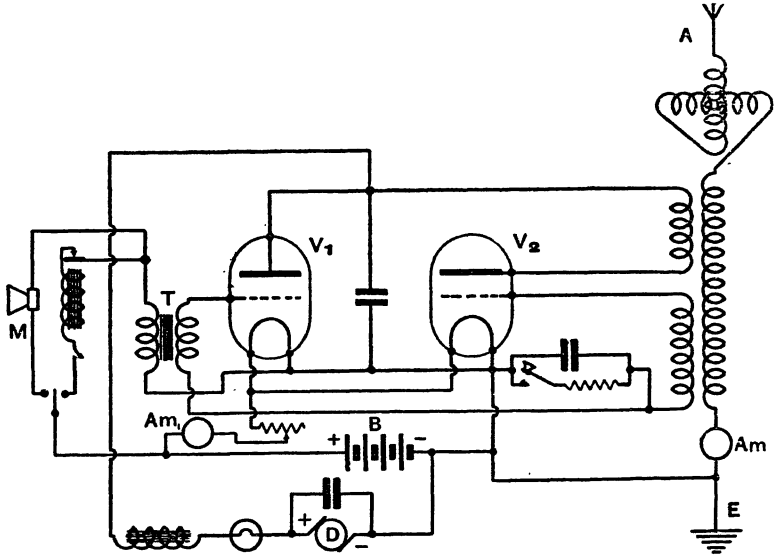

FIG. 11.

* See RADIO REVIEW Abstract No. 461.

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microphone transformer T on the grid of the modulator tube V_1. The amplified audio-frequency output of the modulator tube is then introduced into the anode circuit of the radio frequency generating tube V_2.

It is found that with all these sets the range with a trailing antenna in flight is always greater than that obtained with a skid fin antenna in water.

A one-valve transmitter designed by the Marconi Wireless Telegraph Company has also been used in the large flying boats and dirigibles, but as no modulation amplifier was included the modulation was found inferior to that of the Western Electric circuits.

The difficulties of aircraft reception due to acoustic disturbances (wind-rush and engine noise) and electrical disturbances (induction from engine ignition system) are discussed and the type of helmet-receiver finally developed described. Of the two valves used mainly in receiver circuits one is of the coated filament type and was designed by the Western Electric Company, while the other possesses a tungsten filament and is of Navy Department design. The receivers are mainly of the ordinary type with one tube with inductive coupling for regeneration and detection and two further stages of audio frequency amplification with iron-cored transformer coupling; though newer amplifiers with three stages of radio-frequency amplification have been developed.

The development of radio compass work has been on the lines of the balanced maximum method, using a main and an auxiliary coil at right angles to one another, similar to the arrangements used in the British R.A.F.*

The complete radio compass therefore includes main and auxiliary coils, a reversing switch, a compensating device for the auxiliary coil when it is omitted from the circuit, a tuning device for the system and a receiver. Most of the sets actually used have had revolving coils mounted within the bodies of the flying boats and dirigible cars.

For telephonic communication with aircraft U.S. naval air stations are to be equipped with a standard generator designed by the General Electric Company with a range of 200 nautical miles. A system of remote control conducted over the regular telephone lines is being developed.

560. THERMAL EXPANSION OF INSULATING MATERIALS. W. H. Souder and P. Hidnet. (*Bulletin of Bureau of Standards*, 15, pp. 387—417. *Bureau of Standards Scientific Paper*, No. 352, December 27th, 1919.)

This paper contains selected results of an extensive research upon the thermal expansion of insulating materials. The following materials were investigated: porcelain, bakelite, condensite, formica, celluloid, hard rubber, marble and limestone. The range of expansion coefficients was found to vary between $1{\cdot}6 \times 10^{-6}$ for certain porcelains and $10{\cdot}9 \times 10^{-6}$ for a specimen of celluloid. A summary is first given of the previous work on the expansion of porcelain and marble, and this is followed by a description of the apparatus used in this research. Each specimen tested was in the form of a straight rod of about one square centimetre cross section and 30 cm. in length. The specimens were heated in a furnace and the expansions measured by microscopes. Several tables and a number of curves are given summarising the results obtained for the various specimens tested. The test on various specimens of porcelain showed that this material exhibited no marked permanent set or change in dimensions due to the heat treatment. Porcelains having low coefficients of expansion were found to exhibit marked resistance to sudden temperature changes. On the other hand the various types of bakelite and similar materials generally showed marked diminution in length after heating and cooling again to room temperature.

* See RADIO REVIEW, 1, pp. 213—219, 265—275, February and March, 1920.

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Most of these phenol condensation products—bakelite, condensite, formica, hard rubber and celluloid—when kept at some constant temperature above 60° C., showed a shrinkage in length, and lost weight by giving off vapour. When the temperature of the material increases it expands, but when kept at a constant temperature above 60° C. it contracts.

After heating, each specimen of marble was found to show an increase in length. This growth was approximately the same whether the specimen was heated by cycles or heated directly to the maximum temperature. Repeated heatings tend to bring the marble to a constant or permanent state. On cooling below room temperature the specimens expand again contrary to the usual behaviour of most materials and this peculiar phenomenon of minimum length was common to all the specimens tested. Length measurements made after a period of two years indicated that the growth of marble after heating is permanent. The data given in the paper as to the thermal behaviour of these materials should be valuable when considering their use in various forms of apparatus.

561. RESONANCE AND IONISATION POTENTIALS FOR ELECTRONS IN THE MONATOMIC GASES ARGON, NEON AND HELIUM. H. C. Rentschler. (*Physical Review*, 14, pp. 503—515, December, 1919.)

A special type of three-electrode valve was employed for these experiments. The results indicated a resonance potential of 12 volts and an ionising potential of 17 volts for argon, while neon and helium did not show resonance potentials.

562. THE IONISATION GAUGE. S. Dushman and C. G. Found. (*Journal of the Franklin Institute*, 188, p. 819, December, 1919.)

563. REFLECTION OF ELECTRONS FROM METAL SURFACES. H. M. Dadourian. (*Physical Review*, 14, pp. 434—439, November, 1919.)

564. THE FUSION OF TUNGSTEN. (*Scientific American*, 121, p. 420, October, 1919.)

Describes a new process of working this metal, due to Hugo Lohman, of Berlin. In view of the extensive use of tungsten for the manufacture of triode filaments the process is important as it is said to be the first to afford any promise of fusing the metal into pieces large enough to give wires of all required gauges.

565. HIGH FREQUENCY CURRENTS ON WIRES. J. O. Mauborgne. (*Physical Review*, 14, pp. 452—453, November, 1919.)

An abstract of a paper presented to the American Physical Society dealing with the subject matter referred to in RADIO REVIEW Abstract No. 175, January, 1920.

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566. THE AUGEREAU SYSTEM FOR THE RECEPTION OF SIGNALS ON LOCOMOTIVES. (*Revue Générale de l'Électricité*, 7, pp. 506—507, April 10th, 1920.)

In the arrangement described a horizontal aerial is stretched out alongside the railway track, and a small aerial is mounted on each side of the locomotive. A simple form of spark transmitter controlled by the position of the signals is joined to the fixed aerial, and a coherer receiver employed on the locomotives to operate the necessary indicating apparatus.

567. AN AUTOMATIC WIRELESS TRANSMITTING MECHANISM FOR SIGNAL BUOYS. W. E. Sansom. (*British Patent* 135441, June 20th, 1919. Patent accepted, November 27th, 1919.)

The transmitting mechanism comprising accumulator battery, motor generator and transmitting apparatus, and an automatic signalling key operated by a message drum upon which the message to be sent is set up, is all contained inside the casing of the buoy and is arranged to be set in operation by a float switch operated as soon as the buoy is placed in the water. The aerial is mounted on a mast projecting from the upper part of the buoy.

568. INTERNATIONAL SUBMARINE AND RADIO COMMUNICATION AS RELATED TO AMERICAN COMMERCE. J. J. Rogers. (*Telegraph and Telephone Age*, 37, pp. 614—617, December, 1919.)

Deals with international communications and the need for effective legislation.

569. EMPIRE WIRELESS CHAIN. (*Electrical Review*, 85, p. 690; also p. 675, November, 1919. *Electrician*, 83, p. 597.)

Particulars of the Committee appointed by the British Government to advise *re* Imperial Wireless Communications.

570. LONG-DISTANCE TELEGRAPHY AND GERMAN "WELT-POLITIK." H. Thurn. (*Elektrotechnische Zeitschrift*, 41, p. 36, January, 1920.)

Review of a book by Dr. R. Hennig entitled "Überseeische Telegraphie und Auswärtige Politik."

571. REGULATION OF RADIO BY DEPARTMENT OF COMMERCE FAVOURED. (*Electrical World*, 75, p. 565, March 6th, 1920.)

A summary of a number of suggestions made by J. L. V. Hogan relative to Federal regulation of radio communications.

572. DIRECT COMMERCIAL WIRELESS WITH ENGLAND ESTABLISHED. (*Electrical World*, 75, p. 565, March 6th, 1920.)

Refers to the reopening of the direct commercial wireless service between England and America *via* the New Brunswick (N.J.) radio station.

573. LICENCES FOR WIRELESS TELEGRAPHY. (*Electrician*, 83, p. 598, November, 1919. *Wireless World*, 7, p. 535, December, 1919.)

Particulars of regulations *re* experimental radio licences.

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574. WIRELESS METEOROLOGICAL INFORMATION TO AND FROM SHIPS AT SEA. (*Admiralty Notice to Mariners*, No. 8 of 1920.)

A *résumé* is given of plans for collection and distribution of meteorological data, and a list of wireless stations sending weather reports.

575. THE TIMES OF TRANSMISSION AND THE CHARACTERISTICS OF THE PRINCIPAL WIRELESS STATIONS. (*Revue Générale de l'Électricité*, 6, p. 135B, November, 1919.)

A table setting out the data of a number of large stations.

576. GENERAL INFORMATION WITH REGARD TO WIRELESS TIME SIGNALS. (*London Gazette*, No. 31651, pp. 14057—14059, November 21st, 1919. *Admiralty Notice to Mariners*, No. 7 of 1920. See also *London Gazette*, No. 31788, pp. 2089—2090, February 20th, 1920, and *Admiralty Notice to Mariners*, No. 316 of 1920, for revision of earlier notice.)

A list is given of thirty-six stations throughout the world, which send wireless time signals. The list gives the name of the station, the name of the observatory, the time of sending, the wavelength of transmission and whether sent on " spark " or continuous wave.

577. LONGITUDE BY WIRELESS TELEGRAPHY. (*Nature*, 105, p. 370, May 20th, 1920.)

A scheme for connecting Greenwich and Sydney observatories by radio time signals for accurate determinations of longitude, etc., is discussed briefly.

578. AN ELECTRICAL SIGNALLING METHOD FOR GUIDING CRAFT. R. H. Marriott. (*Telegraph and Telephone Age*, 38, pp. 4—7, January, 1920. *Revue Générale de l'Électricité*, 7, pp. 127—129, January 24th, 1920. *Science Abstracts*, 23B, p. 214, Abstract No. 423, April, 1920, Abstract.) See also R. H. Marriott and H. H. Lister. (*Electrical Review, Chicago*, January 10th, 1920. *Technical Review*, 6, p. 385, April 27th, 1920, Abstract. Also *Electrical Experimenter*, 7, p. 746, December, 1919; *La Nature*, 48, pp. 167—168, April 10th, 1920.)

Paper read before the Seattle Section of the Institute of Radio Engineers.

Vessels can be guided through various channels by means of cables laid along the sides or bottom of the channel, the cables carrying intermittent or alternating currents of audible frequency which are picked up by a coil and telephone receiver carried by the vessel. Outgoing and ingoing routes can be distinguished by sending different signals. Details are given of some experiments at Puget Sound Navy Yard. The author advocates the question being taken up by the Government on account of its great importance, *e.g.* in enabling vessels to enter New York Harbour during fog.

579. PROFESSOR ELIHU THOMSON'S EARLY EXPERIMENTAL DISCOVERY OF THE MAXWELL ELECTROMAGNETIC WAVES. M. B. Snyder. (*General Electric Review*, 23, p. 208, March, 1920.)

Briefly recounts some experiments made by Professor Elihu Thomson in 1875 (twelve years before Hertz's researches) and witnessed by the writer, in which the effects of electromagnetic waves were demonstrated at distances up to 100 feet.

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2. Books.

WIRELESS TELEGRAPHY: A Handbook for the Use of Operators and Students. By W. H. Marchant. (London: *Sir Isaac Pitman & Sons, Ltd.* Second Edition, 1920. Pp. ix. + 305. Price 7*s.* 6*d.* net.)

The writer of a text-book on wireless telegraphy at the present time suffers from the disadvantage that, owing to the rapidity of the progress in the art, he may not only give undue prominence to apparatus which is becoming obsolete, but, what is far more important, he may find that in the period between the time the manuscript left his hands and the time the work is published, new and important methods and apparatus have been developed which should have found a place therein.

The present work, which is a small and elementary text-book, in preparing which the author, as stated in the preface, has chiefly had in mind the seafaring operator and students preparing for the Postmaster-General's certificate, suffers in this manner. At the present moment the three-electrode valve is already being fitted on ships for receiving purposes, and the Marconi Company has commenced to supply direction-finding outfits which will undoubtedly have a great influence on navigation in the future, and will extend that which is perhaps the most important characteristic of the art of wireless telegraphy, its great aid to the saving of life at sea.

The direction finder is not mentioned and the allusions to the three-electrode valve are of the briefest, and no doubt this will be a disappointment to many to whom the book would otherwise appeal.

As will be expected, the theoretical treatment is limited to elementary explanations of a few important conceptions such as "electric oscillations," "electric waves," etc. The explanations given are however clear, and the author has not loaded his book with the chapters on elementary electricity which are often to be found in general text-books on wireless telegraphy.

The work consists of sixteen chapters and a glossary of terms, and is well supplied with diagrams and illustrations. The major portion is devoted to a description of the small-power sets of the Telefunken, Lepel, Poulsen, and Marconi systems. The description of the Marconi ship sets is very thorough; the wiring of all important circuits, including switchboard and power circuits, is given in clearly-drawn diagrams. In fact the treatment of some parts of the apparatus, such as the multiple tuner and magnetic detector, is almost too full, since these are becoming obsolete, while the crystal receiver and three-electrode valve circuits, which in a few years will probably be universally employed, have not had adequate space devoted to them.

The progress in the adaptation of the three-electrode valve to wireless telegraphic and telephonic reception and transmission is so rapid that a large amount of the apparatus which might have been treated of in this work has probably (as in the instance given above) been put on the market whilst it was being printed, but even then a general description of the ordinary types of circuit employed together with an elementary account of the theory

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would be of great service to an operator who may have to use one of these instruments. The space devoted to the three-electrode valve is only four pages, whilst the coherer—which is now of only historical interest—occupies about as much.

The sets described in some detail include the Marconi 1½, ½, and ¼ kW. ship sets, Poulsen, Lepel and Telefunken sets of small power including a Telefunken airship set, and the Goldschmidt alternator. Special chapters are devoted to the transmitter, detector, and receiver, in which the general principles of the circuits and appliances of these parts of a wireless installation are set out.

The twelfth chapter is devoted to measurements, and includes a description of the De Sauty bridge for capacities, and methods for measuring the dielectric losses in condensers, capacities of aerials and resistance, wavelength, coupling and decrement of circuits, together with the strength of received signals, etc. Most of the information given is correct and in keeping with the general style of the book, but the section on measurement of high-frequency current is rather misleading, since, after stating that the ordinary or shunted type of hot-wire ammeter is of no use for measuring high-frequency currents, a description of the Reiss thermometer is given as though it were a convenient instrument for the purpose, and the unshunted (or "shuntless") type of hot-wire ammeter, which is to be found on large numbers of small radio sets, is not mentioned.

It is standard practice with many companies to supply an ammeter with transformer for measuring the aerial current, especially in small continuous wave sets where some indicator of the sort is essential.

The loss due to *eddy currents* in conductors which pass close to an energised aerial is wrongly ascribed as due to its not being *well insulated* for oscillatory currents.

In the thirteenth chapter is given a page of conventional symbols for representing various electrical apparatus in diagrams, and the fourteenth and fifteenth are devoted to the regulations and instructions for stations licensed by the Postmaster-General, with a list of abbreviations and the Morse codes.

The sixteenth chapter gives an account of various faults which may occur and how they may be localised, the Marconi 1½ kW. set being selected as an example.

In the glossary most of the definitions given are correct, although one or two are loosely expressed. The function of a telephone receiver is hardly "to make evident the presence of *oscillatory* currents in the circuits of the receiver." This is the function of the detector which rectifies these currents, the actual current in the telephone being a varying direct current and not an alternating one.

Under miscellaneous receiving apparatus is given a full description of the Brown telephone relay type A, but we believe that where relays of this nature are still used preference is given to the more stable G type employing a carbon microphone cell.

W. H. N.

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ROBISON'S MANUAL OF RADIOTELEGRAPHY AND TELEPHONY, for the use of Naval Electricians. By Captain S. S. Robison, U.S. Navy. Revised by Captain D. W. Todd, U.S.N., and Commander S. C. Hooper, U.S.N. (Annapolis, U.S.A.: *The United States Naval Institute.* London: *S. Rentell & Co.* Fifth Edition, 1919. Pp. 307. Price 10*s.* net.)

This volume is the fifth edition of the work originally written by Lieutenant (now Rear-Admiral) S. S. Robison, U.S. Navy, in 1907. The aim of the author and revisers has been to present the facts of radiotelegraphy and telephony in a form suitable for the use of naval student operators, and it may be admitted at the outset that the general reader who is not interested in the details of working of the U.S. Navy sets will find little in the general wireless sections that is fresh either in facts or treatment. It is natural to compare such a work as this with the volume recently issued by the U.S. Military Signal Corps under the title of "The Principles underlying Radio Communication." The latter volume proves quite clearly that it is not necessary to be inaccurate or to find refuge in hazy phraseology in an elementary treatment of wireless theory, and increases the debt, already large, which all radio workers owe to the Bureau of Standards. The volume under review, in the comparison mentioned, is at an obvious disadvantage.

Of the seventeen chapters of the book the first five deal with general wireless theory, including facts relating to high-frequency currents, production and detection of ether waves, units, and power expenditure and efficiency of sending and receiving apparatus. The treatment throughout is as non-mathematical as possible, but the fact that such statements as the following are allowed to pass in a *fourth* revision seems to indicate that accuracy sometimes suffers at the hands of simplicity:—

"The electric field" [between the plates of two geometrically similar condensers charged to the same potential difference] "when glass is the dielectric is nine times as strong as that created when the medium intervening between the charges is air" (page 35).

"But in all other features receiving circuits are the exact analogue of sending circuits and the detector could occupy the place of the spark gap" (page 68).

"Lines of magnetic force" [inside a permanent magnet] "run from south pole to north pole" (page 13).

The discussion of capacity and condensers could certainly be improved. To verify that it is possible to explain in an elementary way how an alternating current does "pass through" a condenser in terms of the displacement current one need only turn to the other volume of similar pretensions mentioned above.

The subject of the transfer of energy between coupled circuits is illustrated by the very useful analogy of two pendulums connected by a flexible support, [illegible]ler immediately afterwards being introduced to the quenched gap and its advantages. It seems a pity that the way had not been paved for

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this by discussing the trend of events in the mechanical analogy if the primary pendulum is held rigid (corresponding to an open primary circuit) when its energy has been first transferred to the secondary pendulum.

Chapters VI., VII. and VIII. are devoted to detailed descriptions of the transmitting gear of merchant ships and battleships, the subject being treated under the headings of Spark, Continuous Wave and Telephonic Transmitters. The descriptions are adequately illustrated by photographs, circuit and wiring diagrams. The Western Electric Circuit for the modulation of high-frequency oscillations, so ubiquitous in American service sets, is described in detail. The treatment of vacuum tubes is simple and on the whole interesting, though again one meets the old fallacy that a triode functions as an amplifier because the particular anode current—grid voltage characteristic is shown with a maximum slope greater than 45°.

Chapters IX. and X. though devoted mainly to the subject of service receivers contain a useful discussion of the problems of reception in general including short accounts of very recent American progress such as the experiments of Commander A. H. Taylor on underground antennæ, Weagant's method of reception through interference, and the Alexanderson barrage receiver. Chapter XI. is devoted to a description of the high-power stations of U.S.A., and the following chapter to direction-finding. The description of the radio compass seems unnecessarily laboured seeing that fully six pages are required to point out the directional property of a coil and the ambiguity of the bilateral minima. The naval radio compass set is described in detail and a chapter on aircraft radio concludes the descriptive section of the book.

The remaining four chapters deal with the installation, adjustment, care and operation of sets, wireless procedure and the commercial traffic regulations of the U.S. Naval Communication Service. The section on high-frequency measurements is exceedingly clear so far as it goes, but it requires bringing up to date. For example no mention is made of the now well-known methods of measuring antenna resistance with sustained waves.

The book is illustrated by good diagrams and is in bold readable type—almost free from misprints. No index is included, the only guide to the various sections being a table of contents.

E. V. APPLETON.

Books Received.

ELECTRIC OSCILLATIONS AND ELECTRIC WAVES. By G. W. Pierce. (New York: *McGraw Hill Book Company, Inc.* London: *McGraw-Hill Publishing Co., Ltd.*, 1920. Pp. ix. + 517. Price 30*s.* net.)

THE YEAR BOOK OF WIRELESS TELEGRAPHY AND TELEPHONY. (London: *The Wireless Press, Ltd.* 1920. Pp. 1148. Price 10*s.* 6*d.* net.)

DESIGN AND CONSTRUCTION OF AUDION AMPLIFYING TRANSFORMERS. By E. T. Jones, Assoc.M.I.R.E. (New York: *The Experimental Publishing Company.* 1920. Pp. 16. Price 75 c.)

This little pamphlet gives constructional details for both radio frequency and audio frequency transformers for coupling the stages of a multi-valve amplifier. In the radio

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frequency case details are given of a sectionalised winding with the primary coils sandwiched between the secondary coils, while for the audio frequency case an iron-core transformer is described.

Although the first transformer described is designated as a "radio frequency type" it nevertheless appears to be designed for low frequency amplification subsequent to the detection of the signals, but this point is not made clear either in the text or in the circuit diagrams. This view is strengthened by the statement that the iron-core transformer can be used to replace the air-core one in the same circuit, while no mention is made of the position of the detecting valve in the two cases. Apart from this point, however, the details given appear to be amply sufficient for the construction of such transformers.

P. R. C.

Correspondence.

TRIODE NOMENCLATURE AND SYMBOLS.

To the Editor of the "Radio Review."

SIR,—Dealing further with triode nomenclature and symbols referred to in the March issue of the RADIO REVIEW, may I suggest that the word "amplification" be limited to the domain of actual voltage or current amplification? This would then leave the phrase "relay action" for use in connection with the two mutual conductance ratios $\partial i_a/\partial v_g$ and $\partial i_g/\partial v_a$. That is, the word "relay" would imply the transformation of potential to current or *vice versâ*.

From this standpoint the word "detector" should be limited to a symmetrical relay action. Thus, also, with the range of grid potentials in which no grid current actually flows in a triode, we can refer to a pure relay or detector action.

A. PRESS.

East Pittsburg, Pa.,
April 28th, 1920.

THE KALLIROTRON.

To the Editor of the "Radio Review."

SIR,—I have now seen a copy of Mr. Marius Latour's recently published French specification No. 501472, referred to in his letter of April 19th, 1920. I shall be glad if you will allow me to express my views as to its bearing on the Kallirotron.

The arrangement shown in the figure accompanying Mr. Latour's letter can not, in my opinion, correctly be designated an amplifier. As the patent specification states, "L'invention se rapporte à un système de lampes, à trois électrodes, susceptible de réaliser par le montage même l'équivalent d'une impédance négative de valeur quelconque." This is the whole of the "Résumé" of the specification, and the single arrangement disclosed is that illustrated in Mr. Latour's letter. That a negative impedance can be used in the construction of an amplifier of E.M.F. is well known—witness the elementary alternating-current laboratory experiment with an inductance and a capacity in series, designed to show the student that the P.D. across

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a part may be greater than the P.D. across the whole; but amplifier is surely an inaccurate description of a box of apparatus with only two terminals for connection to an external circuit. The Kallirotron amplifier, on the other hand, is a true amplifier of change of P.D., with two input terminals and two output terminals.

This distinction between Mr. Latour's negative-impedance producer and the Kallirotron amplifier, as shown for example in Figs. 1 and 3 of my paper, is emphasised by a comparison between them when the circuit values are symmetrical in each case. In the former, owing to the absence of anything corresponding to my resistances R_1 and R_2, change of anode potential in either triode never numerically exceeds the change of grid potential; whereas in the latter there is the ordinary amplifier ratio (viz. up to the triode amplification factor $\nu = g/a$) between the anode and grid changes.

In arriving at the ratio between the repeat E.M.F. appearing between the output terminals and the E.M.F. applied between the input terminals of the Kallirotron, the theory was conveniently stated in terms of negative resistance. It is to be noted that the negative resistances are *within* the amplifier, and the external circuit in which the magnified repeat E.M.F. appears has no cognisance of them, nor is its presence necessary to produce them. The negative resistance (expression 9, page 320 of my paper), is a term in the resistance of the anode-filament circuit of a triode; in Mr. Latour's device, the negative impedance appears between the grid of one triode and the anode of another if and when an external circuit is connected across these points. With regard to originality in the negative-resistance presentation, I think my statement on page 317, "It is well understood that the most important effect of such retroaction is the reduction of the ohmic resistance of the circuits," clearly shows that I made no claim in this respect; and I referred to the Dynatron because it was mainly from Mr. A. W. Hull's article that I gained an appreciation of the utility of the conception. I am quite prepared to accept Mr. Latour's statement that he has "been the first to introduce the idea of negative resistance in the conception of certain amplifier connections."

For the rest, asymmetric amplification (rectification) and limiter-amplification, being particular cases of amplification, are not referred to in Mr. Latour's specification. Neither does he mention the use of his device to generate oscillations. It can, of course, be used for this purpose, but the circuits are not the same as those of Fig. 8 of my paper. The ingenious division of the anode batteries into two parts in order to make grid batteries unnecessary, as described by Mr. Latour, seems an excellent arrangement.

L. B. TURNER.

King's College, Cambridge.
June 12th, 1920.

ERRATUM.

Page 397, *Abstract No.* 355 (*May*, 1920), *the* "*Radio Review*" *reference should read:* 1, pp. 178—181, January, 1920.

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THE RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. I AUGUST, 1920 NO. 11

Editor:
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THE
RADIO REVIEW

VOL. I AUGUST, 1920 NO. 11

The Effect of Ionization on a Characteristic Curve of a Three-Electrode Valve containing a Trace of Gas.*

By B. HODGSON, O.B.E., M.Sc., Ph.D., and L. S. PALMER, B.Sc.

The phenomena to be described afford a simple and quick method of determining with relatively coarse measuring instruments the potential through which an electron must fall to produce ionization.

If the grid of a "hard" valve is maintained at a constant potential v positive with respect to the negative end of the filament and the plate potential V varied, the characteristics shown in Fig. 2 can be obtained. Fig. 1 shows the circuit used for obtaining them.

These characteristics differ from those commonly figuring in radio-telegraphy—in that the grid current i and the plate current I are given as functions of V (v being constant), instead of functions of v (V being constant). The dotted curve shows the variation of grid current i with plate voltage V.

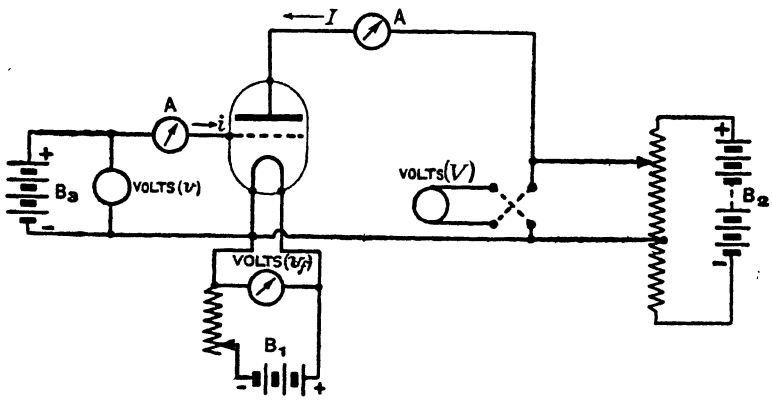

FIG. 1.

* Article received April 21st, 1920.

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The current to the grid increases as the plate potential increases up to the value $V = 0$ and then steadily decreases. The full curve of Fig. 2 shows the variations of the plate current I over the same range.

Up to the point $V = 0$, the grid takes practically all the current, since

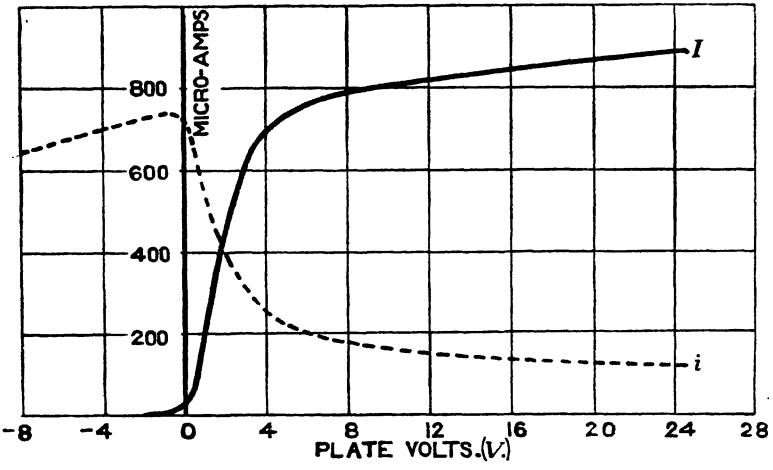

FIG. 2.

those electrons which pass through the grid wires are turned back to the grid by the retarding field between the grid and plate. When V becomes positive the plate current begins and increases with V very rapidly—more rapidly in fact than the electron emission from the filament in the case of an open grid valve, so that the grid current i decreases as V increases.

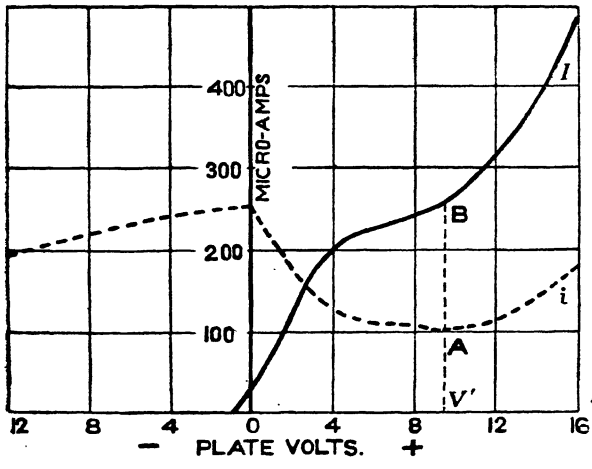

FIG. 3.

In the case of a valve containing a trace of gas the (i — V) characteristic is shown by the dotted curve of Fig. 3. The grid current with V positive and increasing does not decrease continuously but at a point A (Fig. 3) commences to increase. This can be explained in the following way. When the plate po-

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tential is such that the electrons passing through the grid can acquire sufficient energy to ionize the gas by collision, then ionization will occur near the plate and some of the positive ions produced there will pass to the grid and some—the larger portion in the case of an open grid valve—will pass to the filament. This bombardment of the filament by positive ions produces an increased emission of electrons. It is this increased emission of electrons that yields to the grid the increased current at the point A on the dotted curve of Fig. 3, and to the plate, the increase shown at B on the full line curve of the same figure. The hard valve characteristics of Fig. 2 preclude any explanation of the increase in grid current due to the emission of positive ions from the grid wires or plate by electronic bombardment, for such emission would occur whether a gas were present or not.* The plate voltage V' (Fig. 3), at which the change in current is indicated is not the ionizing potential because the electrons are emitted from the filament with varying velocities and because the majority of them come from the mid-point of the filament—*i.e.*, from the hottest part of it. Thus the energy possessed by the majority of the electrons on arriving near the plate is that obtained by falling through a voltage of $V' - \frac{v_f}{2} + e$ where v_f is the voltage fall along the filament and e is the emission velocity of those electrons from the mid-portion of the filament. In the case of the audion which had a V filament the expression becomes $V' - \frac{v_f}{4} + e$. The method does not claim to be a precision method for finding the ionizing potential—but it gives results in good agreement with those obtained by other observers.

The value of e was obtained by a method similar to that adopted by Van der Bijl.† A small positive potential was applied to the plate, causing a small plate current to pass through a galvanometer. The grid potential was made negative so that this current just became zero. Then $-v = \gamma V + e$ where γ is a constant depending upon the geometrical arrangement of the electrodes. By obtaining zero current with two different values of v and V, γ can be eliminated and e found. Some electrons of greater emission velocity will be present in numbers too small to be indicated by the galvanometer, but as a coarser current measuring instrument was used to detect the ionization, no great error will be introduced by neglecting these.

The valves used were the N.P.L. No. 2 valve containing mercury vapour, the R2A receiving valve containing helium; an R receiving valve filled with pure argon to a pressure of 0·5 mm. Hg., and the audion—an air valve. In this valve the oxygen would be absorbed by the tungsten filament and finally sputtered to the sides of the valve as tungsten oxide, leaving as a gas residue nitrogen.

The values of e were measured before and after the ionizing voltage was found and the mean value used. The decrease in the value of e is due to the increase in resistance of the filament with use, caused by evaporation of the tungsten.

* *Proceedings of the Royal Society*, 95A, p. 408, April 1st, 1919.
† H. J. van der Bijl (*Physical Review*, 12, p. 171, 1918).

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The voltage along the filament was kept constant during the experiments —and not the current through it.

Some values of e are given in Table I.

TABLE I.

Valve.	e		Mean e.	v_f
	Before.	After.		
N.P.L. No. 2 .	1·96	1·88	1·92	3·0
R2A . .	1·50	1·25	1·37	3·0
Audion . .	1·79	1·68	1·74	3·5
R (argon) .	—	—	3·9	3·4

Fig. 4 represents a family of curves obtained with the N.P.L. No. 2 valve. They represent the $(i - V)$ characteristics for different values of grid potential v, the filament voltage v_f being constant.

Fig. 5 shows the $(i - V)$ characteristics with constant v and varying v_f.

It will be seen from Figs. 4 and 5 that the sharpest bend on the $(i - V)$ curve is obtained when v_f is as big as possible and when v is nearly the ionizing potential.

From Fig. 5 it will also be seen that below a certain filament temperature there is no tendency for the current to increase when the plate potential reaches the value of the ionizing potential, because the number of collisions has decreased so much that the resulting ionization is inappreciable.

Some results for the ionizing potential for mercury are given in Table II.

TABLE II.—N.P.L. No. 2 VALVE.

V'	v	Mean e.	v_f	Ionizing potential (volts).
9·8	8	2·2	3·0	10·5
9·4	6	2·2	3·0	9·9
9·6	4	2·2	3·0	10·3
9·5	2	2·2	3·0	10·2
10·4	8	1·6	2·95	10·5
10·3	6	1·6	2·95	10·4
9·8	4	1·6	2·95	9·9
9·7	8	2·2	3·0	10·4
10·0	8	1·9	3·0	10·4
11·5	8	0·1	2·0	10·6
11·0	8	0·2	2·1	10·2

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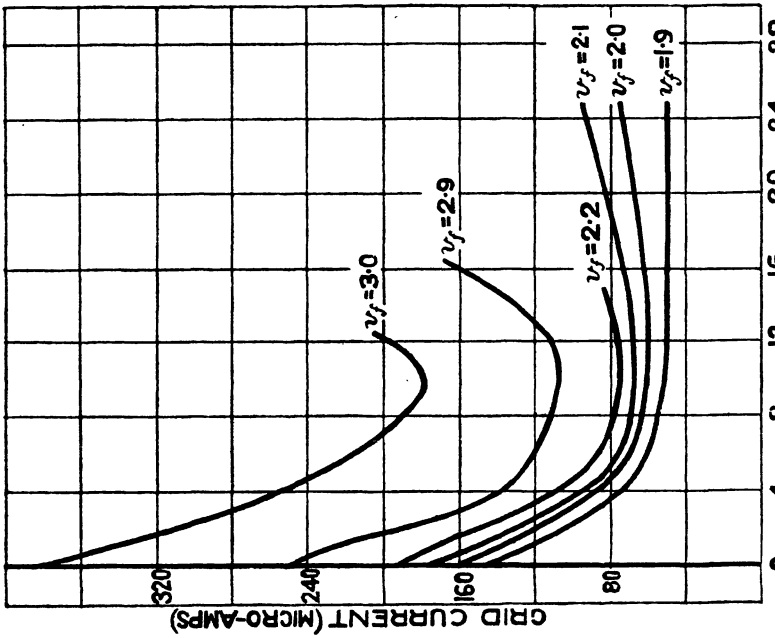

FIG. 5.

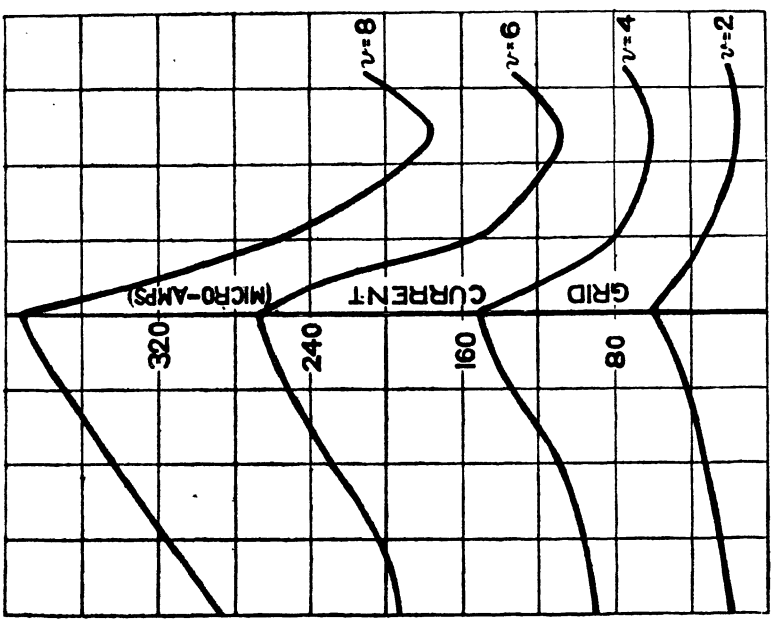

FIG. 4.

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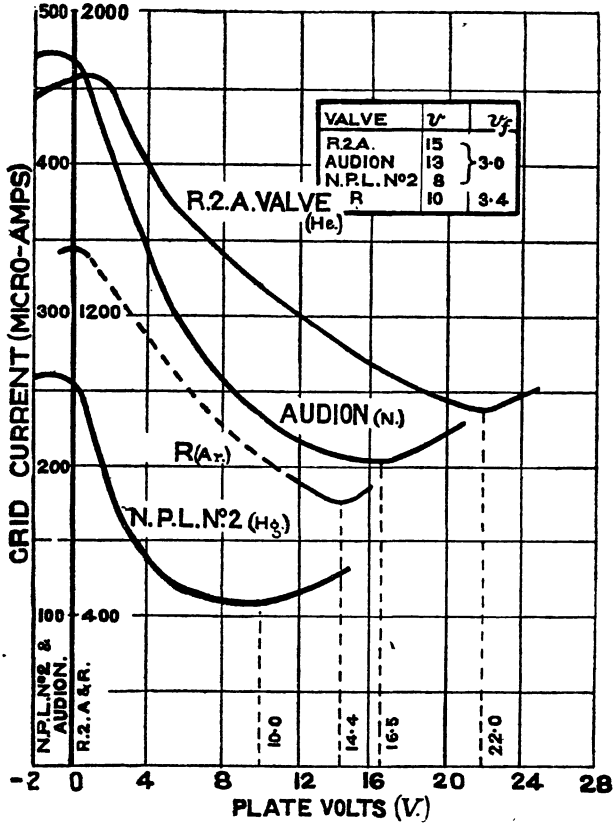

FIG. 6.

The mean value obtained from these experiments is 10·3 volts.

Typical curves from the four valves in question with the corresponding numerical data are given in Fig. 6 and Table III. respectively.

The values for the ionization potentials of mercury vapour, nitrogen, argon and helium are found to be 10·4, 17·4, 16·6 and 21·9 volts respectively.

The value obtained for mercury vapour agrees with the generally accepted value. In the case of nitrogen Davis and Goucher * obtained 18·5 volts, whilst Smyth † obtained a value of about 18 volts as the ionizing potential. Other observers have obtained 7·5 volts which is in all probability a resonance potential. The results obtained by the present method tend to confirm

TABLE III.

Valve.	V'	v	Mean e.	v_f	Ionizing potential (volts).
N.P.L. No. 2 (Mercury vapour). . .	10·0	8·0	1·9	3·0	10·4
Audion (Nitrogen) .	16·5	15·0	1·7	3·5	17·4
R (Argon) . .	14·4	13·0	3·9	3·4	16·6
R2A (Helium) . .	22·0	10·0	1·4	1·5	21·9

* B. Davis and F. S. Goucher (*Physical Review*, 13, pp. 1—5, January, 1919).
† H. D. Smyth (*Physical Review*, 14, pp. 409—426, November, 1919).

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the higher value as the true ionization potential of nitrogen. The value of 16·6 volts for the ionization potential of argon is in accordance with the result of 17 volts recently found by Rentschler.* Horton † obtained a value of 15·1 volts, with a marked increase in the ionization when the potential fall was increased to values ranging from 17 to 21 volts. In the case of helium there is considerable divergence of opinion as to its ionizing potential. Till recently 20·5 volts was generally accepted as the voltage through which an electron must fall to gain energy enough to ionize, but Richardson and Bazzoni found 29 volts ‡ and both Horton § and Rentschler * about 26. The present work indicates 22 as an upper limit for the ionizing potential. It was thought possible that the ionization indicated might be due to collisions—coincident in time—of two electrons with one molecule. To test this point the filament temperature was lowered just so far that ionization was not detectable at 22 volts, and V was then increased up to

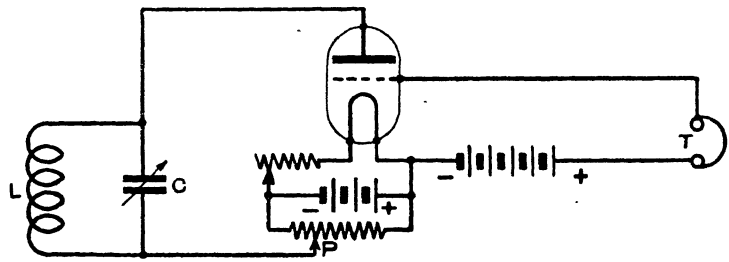

FIG. 7.

50 volts, but no ionization was observed, and with no adjustment of filament temperature could ionization be detected except at 22 volts.

The upper bend in the $(i - V)$ characteristic suggests a new use of the valve as a detector of wireless signals. The rectification will be most efficient when the plate voltage V is approximately zero, since at this value the plate current is just commencing.

Fig. 7 shows the electrical arrangements for this use of the valve, but it was found that this method gave results decidedly inferior to any of the valve methods in general use.

SUMMARY.

The $(i - V)$ characteristic of a soft three-electrode valve yields a quick method of obtaining the ionizing potential of a gas.

Physics Department,
The University, Bristol.

* H. C. Rentschler (*Physical Review*, 14, pp. 503—515, December, 1919). See also RADIO REVIEW Abstract No. 561, July, 1920.

† F. Horton and Miss A. C. Davies (*Proceedings of the Royal Society*, 97A, pp. 1—22, March 1st, 1920).

‡ O. W. Richardson and C. B. Bazzoni (*Philosophical Magazine*, 34, pp. 285—307, October, 1917).

§ F. Horton and Miss A. C. Davies (*Proceedings of the Royal Society*, 95A, pp. 408—429, April 1st, 1919).

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The Diffraction of the Field by a Cylinder and its Effect on Directive Reception on Board a Ship.

By Commandant RENÉ MESNY.

I.—THEORETICAL PROBLEM.

1. Aim of the Paper.—The mathematical investigation developed below was undertaken with the object of discussing the outline of a theory for the deviations observed in a radiogoniometer aboard ship.

The conditions of the theoretical problem that we have assumed differ somewhat from the actual conditions and it is therefore difficult to predict to what extent the results of the calculation should agree with the observations.

As a matter of fact the coincidence is remarkable, and the distribution of the field which we have deduced may be regarded as accurate not only qualitatively but also quantitatively.

2. Nature of the Problem.—We shall consider a plane wave having a wavefront in a vertical plane. The fields are polarised, the magnetic field being horizontal. This wave impinges obliquely on an infinitely conducting cylinder with horizontal axis and we shall determine the field diffracted by the cylinder.

The problem is dealt with in an absolutely general manner, without, however, calculating the harmonics, and in conclusion the practical case is treated in which the radius of the cylinder is small compared with the wavelength.

In virtue of the principle of images, the solution of the problem is also that of the case in which the wave is confined to an indefinite horizontal conducting plane on which a semi-cylinder is resting (Fig. 1).

FIG. 1.

The chief differences between the actual case and the theoretical problem are as follows :—

(1) The ship is not an infinitely long cylinder.

(2) Its transverse section is not circular but nearly rectangular.

(3) The sea is not a perfectly conducting plane.

(4) The metal is likewise not infinitely conducting.

It may be noted that the length of a ship is from six to eight times its width, and about ten times its depth. If the wave direction is not inclined to the axis at too small an angle, the distribution of the field will then be very close to that of the theoretical case.

The second objection is more serious, but the study of a rectangular

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section involves difficult calculations which have not been completed, and as has been said above the results obtained for the circular cylinder are extremely close to the observed values.

As regards the imperfect conductivity of the sea and of the metal (or of the earth if the field on a hill is being considered) there is no need to trouble much about it. If the resistance of these elements is taken into account, it is found that the correcting terms do not exceed one-fortieth of the principal term as long as the conductivity is greater than 10^{-13} e.m. units, which is the average conductivity of damp soil, 10^{-11} being the conductivity of the sea. These correcting terms are moreover proportional to the square root of the conductivity.

3. Notation.—Cartesian co-ordinates x, y, z.
Cylindrical ,, x, ρ, θ.

Components of the magnetic and electric fields in Cartesian co-ordinates X, Y, Z; χ, η, ζ.

Components in cylindrical co-ordinates X, N, T; χ, ν, τ.

Unaccented symbols refer to the fields of the cylinder, whilst those with accents refer to the wave field, unless otherwise stated.

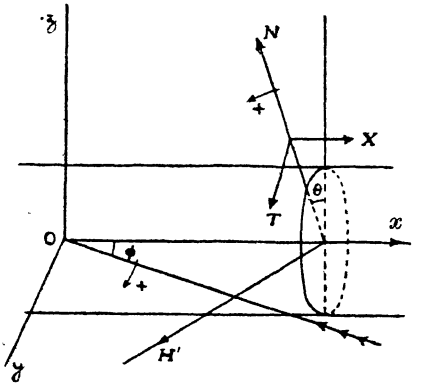

FIG. 2.

ϕ is the angle between the normal to the wavefront and the axis of the cylinder; the positive directions are indicated by arrows in the figures.

Finally, ρ_0 is the radius of the cylinder, and we may put

$$2\pi/\lambda = \alpha; \quad \alpha\rho \sin\phi = r; \quad \tfrac{1}{2}(\alpha\rho_0 \sin\phi) = \beta; \quad \rho_0/\rho = m.$$

Our equations will be expressed in the form due to Hertz, the magnetic quantities being measured in the e.m. system and the electric quantities in the e.s. system.

J and K are Bessel functions of the first and second kind, and Q_n the combination $\left\{ K_n(r) + r\frac{\partial K_n(r)}{\partial r} \right\}$.

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4. Equations.—We have in the Cartesian and cylindrical systems,

$$\left.\begin{aligned} \frac{1}{c}\frac{\partial \chi}{\partial t} &= \frac{\partial Y}{\partial z} - \frac{\partial Z}{\partial y} \\ \frac{1}{c}\frac{\partial \eta}{\partial t} &= \frac{\partial Z}{\partial x} - \frac{\partial X}{\partial z} \\ \frac{1}{c}\frac{\partial \zeta}{\partial t} &= \frac{\partial X}{\partial y} - \frac{\partial Y}{\partial x} \end{aligned}\right\} \quad \ldots\ldots \quad (1)$$

$$\left.\begin{aligned} \frac{1}{c}\frac{\partial \chi}{\partial t} &= \frac{T}{\rho} + \frac{\partial T}{\partial \rho} - \frac{1}{\rho}\frac{\partial N}{\partial \theta} \\ \frac{1}{c}\frac{\partial \nu}{\partial t} &= \frac{1}{\rho}\frac{\partial X}{\partial \theta} - \frac{\partial T}{\partial x} \\ \frac{1}{c}\frac{\partial \tau}{\partial t} &= \frac{\partial N}{\partial x} - \frac{\partial X}{\partial \rho} \end{aligned}\right\} \quad \ldots\ldots \quad (2)$$

where c = the velocity of light.

All these elements satisfy the equation

$$\Delta U = \frac{1}{c^2} \cdot \frac{\partial^2 U}{\partial t^2}$$

which in cylindrical co-ordinates may be written

$$\frac{\partial^2 U}{\partial \rho^2} + \frac{1}{\rho}\frac{\partial U}{\partial \rho} + \frac{1}{\rho^2}\frac{\partial^2 U}{\partial \theta^2} + \frac{\partial^2 U}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 U}{\partial t^2} \quad \ldots\ldots \quad (3)$$

In the steady state, the value of the function U of the system, in a section perpendicular of Ox, and passing through M is the same as it would have in the plane $y\,z$ when the wave had advanced by O P = O M cos $\phi = x \cos \phi$, that is to say at the end of an interval of time equal to $x \cos \phi/c$. The variable x is therefore necessarily associated with t in the expression for U, and these two variables can only occur there together in the form $(t + x \cos \phi/c)$.

We may therefore put

$$U = u\epsilon^{2\pi j\,(t/T\,+\,x\,\cos\,\phi/\lambda)}$$

whence, putting $\alpha = 2\pi/\lambda$ we get

$$U = u\epsilon^{j\omega t} \cdot \epsilon^{j\alpha x \cos \phi} \quad \ldots\ldots\ldots \quad (4)$$

u is only a function of ρ and θ, so that equation (3) becomes

$$\frac{\partial^2 u}{\partial \rho^2} + \frac{1}{\rho}\frac{\partial u}{\partial \rho} + \frac{1}{\rho^2}\frac{\partial^2 u}{\partial \theta^2} = -\alpha^2 \sin^2 \phi u$$

If u is expanded by Fourier's series

$$u = u_0 + u_1 \sin\theta + v_1 \cos\theta + u_2 \sin 2\theta + v_2 \cos 2\theta + \ldots$$

the functions u_n and v_n of ρ will be solutions of the equation :

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$$\frac{d^2u_n}{d\rho^2} + \frac{1}{\rho}\frac{du_n}{d\rho} + \left(\alpha^2 \sin^2\phi - \frac{n^2}{\rho^2}\right) u_n = 0$$

Putting $\rho\alpha \sin \phi = r$, this equation may be transformed into

$$\frac{d^2u_n}{dr^2} + \frac{1}{r}\frac{du_n}{dr} + \left(1 - \frac{n^2}{r^2}\right) u_n = 0$$

for which the solutions are Bessel functions of the n^{th} order.

The functions K correspond to the actual problem, so that we may put

$$u_n = 2A_n' K_n(r)$$
$$v_n = 2A_n'' K_n(r)$$

Hence

$$u = A_0K_0(r) + 2\sum_{r}^{\infty} (A_n' \sin n\theta + A_n'' \cos n\theta)\, K_n(r) \quad . \quad . \quad . \quad . \quad (5)$$

Calling U' the value of the element considered if the wave existed alone and the cylinder were not present, it would evidently be a solution of (3). As the total element U is a solution, so likewise will be their difference since equation (2) is linear; in other words the part of U which refers to the field diffracted by the cylinder can be represented by equation (5).

In the following the unaccented symbols will be reserved for the components of an element referring to the diffracted field, while the accented ones will represent the corresponding elements of the wave.

Putting

$$M = \epsilon^{j(\omega t + \alpha x \cos\phi)}$$

we have

$$\left.\begin{aligned} X/M &= A_0K_0(r) + \sum_{1}^{\infty}(A_n' \sin n\theta + A_n'' \cos n\theta)\, K_n(r) \\ Y/M &= B_0K_0(r) + \sum_{1}^{\infty}(B_n' \sin n\theta + B_n'' \cos n\theta)\, K_n(r) \\ Z/M &= C_0K_0(r) + \sum_{1}^{\infty}(C_n' \sin n\theta + C_n'' \cos n\theta)\, K_n(r) \end{aligned}\right\} \quad . \quad . \quad (6)$$

Taking the amplitude of the magnetic field of the wave to be unity, and reckoning the positive direction that in which ϕ increases, we have

$$H' = \epsilon^{j[\omega t + \alpha(x\cos\phi + y\sin\phi)]} = M\,\epsilon^{j\alpha y \sin\phi} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

To combine this with the field of the cylinder it must be expanded by the Fourier series. In this connection it should be noted that $y = \rho \sin\theta$, and we then have

$$H' = M\left\{\begin{aligned} &J_0(r) + 2J_2(r)\cos 2\theta + 2J_4(r)\cos 4\theta) + \ldots\ldots) \\ &+ j\,[2J_1(r)\sin\theta + 2J_3(r)\sin 3\theta + \ldots\ldots] \end{aligned}\right\}$$

where the J_0, J_1, etc., are Bessel functions of the first kind.

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5. Determination of the Coefficients.—The coefficients A_n, B_n, C_n may be determined by the limiting conditions which are given by the tangential electric field being zero on the surface of the conductor and by the magnetic field being perpendicular to it.

For this purpose it is convenient to utilise equation (2), and by noting that the electric field of the wave has no components parallel to the axis of the cylinder, we have for $\rho = \rho_0$,

$$\left.\begin{aligned} N + N' &= 0 \\ \frac{\partial(X + X')}{\partial\rho} &= 0 \\ \frac{T}{\rho} + \frac{\partial T}{\partial\rho} &= \frac{1}{\rho}\frac{\partial N}{\partial\theta} \\ &= -\frac{1}{\rho}\frac{\partial N'}{\partial\theta} \end{aligned}\right\}$$

which for convenience in calculation when $r = r_0$ may be replaced by

$$N = -N' \quad \ldots\ldots\ldots \quad (8)$$

$$\frac{\partial X}{\partial r} = -\frac{\partial X'}{\partial r} \quad \ldots\ldots\ldots \quad (9)$$

$$T + r\frac{\partial T}{\partial r} = -\frac{\partial N'}{\partial\theta} \quad \ldots\ldots\ldots \quad (10)$$

where $r = \alpha\rho\sin\phi$.

We have, moreover,

$$\begin{aligned} N &= Y\sin\theta + Z\cos\theta & X &= -H'\sin\phi \\ T &= Y\cos\theta - Z\sin\theta & N' &= H'\cos\phi\sin\theta \\ & & T' &= H'\cos\phi\cos\theta \end{aligned}$$

and we find by equating the coefficients of $\sin\theta$ and $\cos\theta$ in equations (8), (9) and (10)

$$\frac{X}{M\sin\phi} = \left\{\begin{aligned} &\frac{J_0'(r_0)}{K_0'(r_0)}K_0(r) + 2\frac{J_2'(r_0)}{K_2'(r_0)}K_2(r)\cos 2\theta + \ldots\ldots \\ &+ j\left[2\frac{J_1'(r_0)}{K_1'(r_0)}K_1(r)\sin\theta + 2\frac{J_3'(r_0)}{K_3'(r_0)}K_3(r)\sin 3\theta + \ldots\right] \end{aligned}\right\}$$

$$\frac{N}{M\cos\phi} = \left\{\begin{aligned} &\{D_0K_0(r) - E_2K_2(r)\}\sin\theta + \\ &\qquad + \{D_2K_2(r) - E_4K_4(r)\}\sin 3\theta + \ldots \\ &+ j\left[\frac{J_0'(r_0)}{K_1(r_0)}K_1(r) - \{D_1K_1(r) - E_3K_3(r)\}\cos 2\theta + \ldots\right] \end{aligned}\right\}$$

$$\frac{T}{M\cos\phi} = \left\{\begin{aligned} &\{D_0K_0(r) + E_2K_2(r)\}\cos\theta + \\ &\qquad + \{D_2K_2(r) + E_4K_4(r)\}\cos 3\theta + \ldots \\ &+ j\left[\{D_1K_1(r) + E_1K_1(r)\}\sin 2\theta + \ldots\ldots\right] \end{aligned}\right\}$$

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where

$$D_p = -2J_{p+1}'(r_0)\,\frac{(p+2)K_{p+2}(r_0) + r_0K_{p+2}'(r_0)}{K_p(r_0)Q_{p+2}(r_0) + K_{p+2}(r_0)Q_p(r_0)}$$

$$E_p = -2J_{p+1}'(r_0)\,\frac{(p-2)K_{p-2}(r_0) - r_0K_{p-2}'(r_0)}{K_p(r_0)Q_{p-2}(r_0) + K_{p-2}(r_0)Q_p(r_0)}.$$

6. The Case when ρ/λ is small.—Let us now suppose that the radius of the circle is sufficiently small for $(\pi\phi/\lambda)^2$ to be neglected in comparison with unity, then $(r/2)^2$ will be negligible (since $r = (2\pi\rho \sin\phi)/\lambda$) and the results may be simplified.

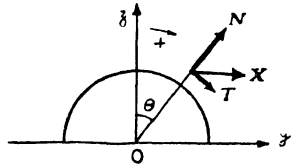

FIG. 3.

This hypothesis is quite permissible if we are considering the effect of a ship on waves of greater length than 600 m., when ρ_0 is in fact less than 15 metres. In this case we have

$$J_0 = 1; \qquad J_0' = -r/2; \qquad K_0 = \log_\epsilon \frac{2\gamma}{p}; \qquad K_0' = -\frac{1}{r}$$

$$J_p = \frac{1}{p!}\left(\frac{r}{2}\right)^p; \qquad J_p' = \frac{1}{2(p-1)!}\left(\frac{r}{2}\right)^{p-1};$$

$$K_p = \frac{1}{p!}\left(\frac{2}{r}\right)^p; \qquad K_p' = -\frac{1}{2(p-1)!}\left(\frac{2}{r}\right)^{p+1}$$

In these expressions γ is Euler's constant, which however will not affect the results. Putting $\beta = r_0/2$ we find,

$$\frac{J_0'(r_0)}{K_0'(r_0)} = 2\beta^2; \quad \frac{J_p'(r_0)}{K_p'(r_0)} = -\beta^{2p}; \quad \frac{J_0'(r_0)}{K_1(r_0)} = -\beta^2; \quad D_0 = 0; \quad D_p = 0;$$

$$Q_p(r_0) = -\frac{p-1}{p!}\beta^{-p}; \qquad E_2 = 2\beta^2; \qquad E_p = p(p-1)\beta^{2p-2}$$

7. Consideration of the Magnetic Field.—Let us further put $r_0/r = \rho_0/\rho = m$, then the expressions for the field become

$$\frac{X}{\epsilon^{j\omega t}} = 2\sin\phi \cdot \epsilon^{j\alpha x\cos\phi}\left\{\beta^2 \log_\epsilon \frac{2\gamma}{r} - \frac{1}{2}\beta^2 m^2 \cos 2\theta + j[-\beta m \sin\theta]\right\}$$

$$\frac{N}{\epsilon^{j\omega t}} = \cos\phi \cdot \epsilon^{j\alpha x\cos\phi}\{-m^2 \sin\theta + j[-\beta m + \beta m^3 \cos 2\theta]\}$$

$$\frac{T}{\epsilon^{j\omega t}} = \cos\phi \cdot \epsilon^{j\alpha x\cos\phi}\{m^2 \cos\theta + j[\beta m^3 \sin 2\theta]\}$$

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Calculating the Y component, $Y = N \sin\theta + T\cos\theta$, of the magnetic field in the plane $y\,z$.

$$Y = \epsilon^{j\omega t} \cdot \cos\phi \{m^2 \cos 2\theta + j[-\beta m \sin\theta + \beta m^3 \sin 3\theta]\} \quad . \quad . \quad (11)$$

Further to study the magnetic field we will neglect the terms in X which involve β^2 so that we can compare this field with others which contain terms independent of β; we then have in the plane $y\,z$

$$X = \epsilon^{j\omega t} \cdot 2\sin\phi \{j[-\beta m \sin\theta]\} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

It is interesting to compare the X and Y components of the field due to the ship with that of the wave, which at the point R in the plane $y\,z$ has by equation (7) the value

$$H' = \epsilon^{j\omega t} \cdot \epsilon^{j\alpha y \sin\phi} = \epsilon^{j\omega t} \cdot \epsilon^{jr\sin\theta}$$

which may be written

$$H' = \epsilon^{j\omega t}(1 + jr\sin\theta)$$

If we evaluate the ratios X/H' and Y/H' the real parts will represent the ratio of the parts of the fields X and Y in phase with H' and the imaginary parts the ratios of the parts of X and Y in quadrature with H'. Writing these ratios as $(X_1 + jX_2)$, $(Y_1 + jY_2)$, and noting that $1/H' = \epsilon^{j\omega t}(1 - jr\sin\theta)$, we have

$$X_1 + jX_2 = j[-2\beta m \sin\theta \sin\phi]$$
$$Y_1 + jY_2 = \{m^2\cos 2\theta + j[\beta m(1 - m^2)\sin 3\theta]\}\cos\phi$$

Finally at a point exterior to the cylinder defined by the co-ordinates ρ and θ, the disturbing magnetic field has the following components in relation to the wave field at this point

Components in phase with the wave field $\left\{\begin{matrix} X_1 = 0 \\ Y_1 = (\rho_0/\rho)^2 \cos 2\theta \cdot \cos\phi \end{matrix}\right\}$ . . (13)

Components in quadrature with the wave field.

$$\left\{\begin{matrix} X_2 = \dfrac{\pi\rho_0}{\lambda}\left(\dfrac{\rho_0}{\rho}\right)\sin\theta\sin^2\phi \\ Y_2 = \dfrac{\pi\rho_0}{\lambda}\left(\dfrac{\rho_0}{\rho}\right)\left[1 - \left(\dfrac{\rho_0}{\rho}\right)^2\right]\sin 3\theta \sin 2\phi \end{matrix}\right\} \quad . \quad . \quad (14)$$

It may be noted that the field in quadrature vanishes if the point R is in

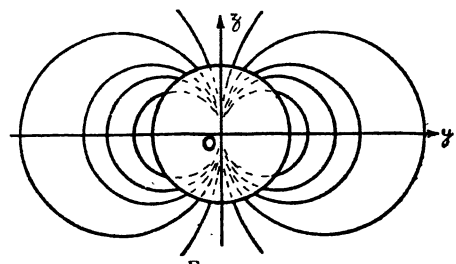

FIG. 4.

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the vertical plane passing through the axis. Further that its component Y_2 is very small compared with X_2 in the neighbourhood of the cylinder.

8. Consideration of the Electric Field. — Substituting the values given by equation (11) in equation (2), we get for a point situated in the plane $y\,z$,

$$\left.\begin{aligned} \chi &= 0 \\ \nu &= \epsilon^{j\omega t}\left\{\begin{aligned} &-\left(\frac{\rho_0}{\rho}\right)^2\cos\theta \\ &+j\left[-\frac{\pi\rho_0}{\lambda}\left(\frac{\rho_0}{\rho}\right)^3\sin 2\theta\sin\phi\right]\end{aligned}\right\} \\ \tau &= \epsilon^{j\omega t}\left\{\begin{aligned} &-\left(\frac{\rho_0}{\rho}\right)^2\sin\theta \\ &+j\left[-\frac{\pi\rho_0}{\lambda}\left(\frac{\rho_0}{\rho}\right)\left\{1-\left(\frac{\rho_0}{\rho}\right)^2\right\}\cos 2\theta\sin\phi\right]\end{aligned}\right\} \end{aligned}\right\} \quad . . (15)$$

whence

$$\eta = \epsilon^{j\omega t}\left\{\begin{aligned} &-\left(\frac{\rho_0}{\rho}\right)^2\sin 2\theta \\ &+j\left[-\frac{\pi\rho_0}{\lambda}\left(\frac{\rho_0}{\rho}\right)\cos\theta\sin\phi+\frac{\pi\rho_0}{\lambda}\left(\frac{\rho_0}{\rho}\right)^3\cos 3\theta\sin\phi\right]\end{aligned}\right\}$$

$$\zeta = \epsilon^{j\omega t}\left\{\begin{aligned} &-\left(\frac{\rho_0}{\rho}\right)^2\cos 2\theta \\ &+j\left[\frac{\pi\rho_0}{\lambda}\left(\frac{\rho_0}{\rho}\right)\left\{\sin\theta-\left(\frac{\rho_0}{\rho}\right)^2\sin 3\theta\right\}\sin\phi\right]\end{aligned}\right\}$$

The real part of this field ν_1, τ_2, represents the part in phase with the electric field of the wave along the axis Oz.

From the expressions

$$\nu_1 = -\epsilon^{j\omega t}\left(\frac{\rho_0}{\rho}\right)^2\cos\theta$$

$$\tau_1 = -\epsilon^{j\omega t}\left(\frac{\rho_0}{\rho}\right)^2\sin\theta$$

for the field in phase with the wave field at O we can easily show that the lines of force of this field are circles, tangent to Oz at O (Fig. 4).

The field in quadrature is very small in comparison with the above and is not of interest for the problem in hand.

The electric field of the wave is given by the third equation of (1). We find for a point in the plane $y\,z$

$$\zeta' = -\epsilon^{j\omega t}\,.\,\epsilon^{j\alpha y\sin\phi}$$

or

$$\zeta' = -\epsilon^{j\omega t}\,(1+j\alpha y\sin\phi)$$

Comparing the principal components of the fields due to this wave and to the cylinder we arrive at the following conclusions :—

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(*a*) In the neighbourhood of the vertical plane through the axis of the cylinder, the field due to the cylinder is in the same direction as that due to the wave. They therefore add together arithmetically.

(*b*) At the surface itself the field due to the cylinder is equal to that due to the wave, so that the total field is double that which would be present without the cylinder.

(*c*) The field due to the cylinder is inversely proportional to the square of the distance from the axis.

(*d*) These properties of the electric field are independent of the direction of the wave.

(*To be concluded.*)

The Efficiency of Aerials.

By THE EDITOR.

Of the total power supplied to the aerial of a transmitting station a portion is dissipated in the resistance of the wires constituting the aerial, tuning coils, secondary winding of the oscillation transformer, and earth or counterpoise wires, a portion is dissipated in imperfect dielectrics situated in the electric field, such as wooden masts, buildings, soil, etc. and a portion is radiated. If R be the total effective resistance of the aerial and I the root-mean-square current, we may write

$$I^2R = I^2(R_w + R_d + R_r)$$

where the suffixes w, d, and r refer to wires, dielectrics and radiation, respectively. Of the three terms the first can be calculated with considerable accuracy and can be kept small by suitable design, the third can also be calculated with some degree of confidence, but it is very difficult to form even a rough estimate of the second term.

The power radiated from an antenna of height h at a wavelength λ is equal to $1584(h/\lambda)^2I^2$ watts on the assumptions that the upper capacity is so large that the current has the same value at every point of the vertical wire and that the height is small compared with the wavelength. The latter assumption is usually justified, and any doubt as to the former is removed by taking h to be the effective height, which is less than the actual height by an amount which can be calculated approximately in many cases. The radiation resistance R is therefore equal to $1584(h/\lambda)^2$ and is inversely proportional to the square of the wavelength. With regard to the dielectric losses it is known that the power-factor of a condenser, *i.e.*, the ratio of the power dissipated to the product of current and voltage is approximately independent of the frequency. Hence I^2R_d bears a fixed ratio to IV where V is the voltage to which the aerial is charged, or, since $I = \omega VC$ and $IV = I^2/(\omega C)$, R_d must bear a fixed ratio to $1/(\omega C)$ and ωCR_d must be

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constant. R_d is therefore inversely proportional to the frequency or directly proportional to the wavelength. Now not only can R_w be made small but it is less dependent on the frequency than either R_r or R_d. If the wavelength is increased by inserting additional turns in the inductance, the conductor resistance would thereby tend to increase, but this would be counteracted to some extent, if not entirely, by reduced skin-effect. As an approximation R_w may therefore be regarded as constant, and the equation $R = R_w + R_d + R_r$ may be written

$$R = a + b\lambda + \frac{c}{\lambda^2}$$

where a, b, and c are constants.

$$\frac{dR}{d\lambda} = b - \frac{2c}{\lambda^3}$$

If R be plotted against λ, the slope of the curve will therefore be negative for values of λ less than $\sqrt[3]{(2c/b)}$, but positive for higher values of λ. The total effective resistance is a minimum for that value of λ which is equal to $\sqrt[3]{(2c/b)}$. Calling this value of the wavelength λ_m, we have

$$\lambda_m = \sqrt[3]{\frac{2c}{b}}$$

and for the value of the total effective resistance at this wavelength we have

$$\begin{aligned} R_m &= a + b\lambda_m + \frac{c}{\lambda_m^2} \\ &= a + \frac{2c}{\lambda_m^3} \cdot \lambda_m + \frac{c}{\lambda_m^2} \\ &= a + \frac{3c}{\lambda_m^2} = a + 3R_{rm} \end{aligned}$$

where R_{rm} is the radiation resistance at the wavelength λ_m.

The total resistance is a minimum for that wavelength at which the dielectric losses are twice the radiated power. From the observed values of R at three different wavelengths it should be possible to calculate the three constants a, b, and c, and thus determine the three component resistances, but the measurements would have to be made with special care to give accurate values. If it be assumed that R_w is negligibly small, then at the wavelength λ_m, the radiation resistance is a third of the measured total resistance, and therefore

$$\frac{R_m}{3} = 1584\,\frac{h^2}{\lambda_m^2}$$

from which the effective height can be calculated.

In the *Bulletin of the Bureau of Standards** L. W. Austin has given curves showing the measured effective resistances of a number of aerials at various

* *Bulletin of the Bureau of Standards*, 9, pp. 65—72, 1913.

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frequencies. Although the data given are rather scanty, we have applied the above formula to each case with the results shown in the following table:—

Aerial.	Length. Metres.	Capacity 10^{-9} farads.	Height. Metres.	λ_m	R_m	Effective Height.
Bureau of Standards, harp .	42·6	1·26	54·8	700	11·5	34·3
Signal Corps, flat top . .	44·5	1·71	39·6	1,300	6·7	48·5
Capitol, flat top . . .	85	2·32	44·2	1,000	7·0	38·0
Navy Yard, harp . . .	51·8	0·73	54·8	900	5·0	29·4
U.S.S. *Maine*, flat top . .	32·9	1·25	38·4	800	2·25	17·4
U.S.S. *Massachusetts*, flat top .	24·4	1·10	39	1,000	2·75	24·1
Arlington, sloping top . .	—	9·4	137 to 183	7,000	1·1	107

The last column gives the effective heights calculated in this way on the assumption that the wire resistance R_w is negligible; it is certainly not negligible but in the absence of further data it can only be said that the actual values of the effective heights must be less than these calculated values, and in some cases probably very much less. It has been stated that the Arlington antenna has an effective height of 137 metres, but how this was determined we do not know; the above calculation indicates a much smaller value. It should be pointed out that this aerial is supported by three steel towers in which currents will flow in opposition to that in the vertical portion of the aerial, thus reducing the radiated power for a given aerial current and lowering therefore the effective height. Insulating the feet of the towers instead of connecting them to the earthing system may reduce these currents to some extent, at the expense, however, of additional dielectric losses in the neighbourhood of the feet of the towers. The aerial together with the towers form a system of partially closed loops, and the losses in the towers should be included in I^2R_w.

The San Paolo aerial at Rome is supported by three wooden lattice towers 218 metres high; it is stated* that it has a minimum resistance of 3·25 ohms at a wavelength of 7,000 metres. Reception tests on a calibrated frame aerial indicate an effective height of 138 metres. Neglecting R_w the above formula gives an effective height of 183 metres; to obtain 138 metres, one must assume the conductor resistance R_w to be 1·4 ohms. This is an improbably high value of R_w and tends to confirm the doubt expressed in the paper referred to as to the accuracy of the measured resistances with undamped waves. Fig. 1 shows the measured effective resistance of the San Paolo aerial at various wavelengths. The curve is plotted from values calculated from the formula $R = 0{\cdot}5 + 0{\cdot}26\lambda + 54{\cdot}3/\lambda^2$. This formula gives the minimum resistance at a wavelength of 7·5 kilometres.

* *Proceedings of the Institute of Radio Engineers*, 8, p. 142, April, 1920. RADIO REVIEW Abstract No. 538, July, 1920.

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It is evidently desirable that very accurate measurements should be made of the total effective resistance at various wavelengths of different types of aerials making allowance for the high-frequency resistance of the aerial, tuning coils, and earth wires, or counterpoise. By making such measurements on aerials with steel masts and wooden masts, with earthing wires and insulated counterpoises, much valuable information would be gained as to

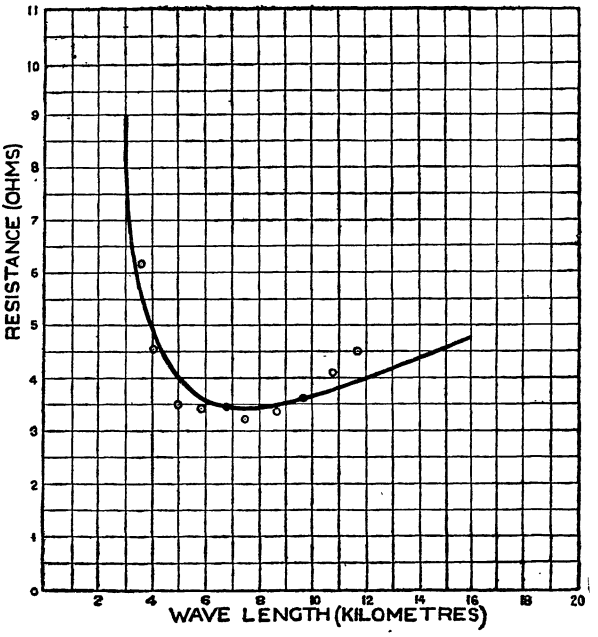

FIG. 1.—SAN PAOLO (ROME) AERIAL.

The points marked are measured values. The curve is plotted from the equation $R = 0{\cdot}5 + 0{\cdot}26\lambda + 54{\cdot}3/\lambda^2$.

the magnitude of the losses and as to the use or misuse of every kilowatt generated. With the limitations at present imposed by the stage of development reached in the construction of large thermionic valves, the last-named consideration is one of the greatest importance.

The Report of the Imperial Wireless Telegraphy Committee, 1919-1920.

The committee which was appointed on November 24th, 1919, by the Secretary of State for the Colonies, "to prepare a complete scheme of Imperial wireless communications in the light of modern wireless science and

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Imperial needs" published its report at the end of June. The report covers twenty-eight pages and can be obtained from His Majesty's Stationery Office for sixpence. We propose here to do no more than review its main features.

As the result of continuous watches kept by the Post Office on the work of the chief European long range wireless stations, the committee came to the conclusion that the services do not reach a satisfactory commercial standard and they state that they are of opinion that no satisfactory commercial wireless service, as they define the expression, is in operation anywhere to-day over a distance exceeding 2,000 miles. For distances over 2,000 miles the power required increases as the sixth power of the distance. The power considered necessary for the transatlantic service has gradually grown from 25 kW., with which Mr. Marconi attempted it in 1901 to 1,000 kW. which is the power of the Poulsen arc being installed at Bordeaux and this in spite of the vastly increased sensitiveness of the receiving apparatus. The committee therefore recommend that the links in the Imperial chain be not greater than 2,000 miles each. With the exception of the Poulsen arcs at present being constructed for the Oxford-Cairo service, the committee recommend the use of thermionic valve generators for all the transmitting stations. The merits and demerits of the various systems are discussed and the reasons set out for the policy recommended. At the request of the Imperial Communications Committee, the proposal put forward by the Marconi Company was considered and is discussed in the report. The committee decided against it on various grounds, but mainly on the ground that the scheme is so ambitious and costly that the possibility of its financial success is very remote. They report that from the point of view of wireless technics the Marconi Company's proposal is much too vague to allow of useful comment.

The committee recommends that the former German station at Windhuk, which is connected with Cape Town by land lines, be fitted up at once as a valve transmitting station to communicate with Cairo *viâ* a new station to be erected at Nairobi.

To carry out their suggestions the committee recommends the appointment of a Wireless Commission of about four members to plan the stations, the construction of which would be carried out by the engineering departments of the Post Office. The committee consider that the complete chain of eight or ten stations could be completed within two years of the issue of plans and specifications. They recommend that long distance wireless traffic with foreign countries be left to commercial companies. "Both services would profit by this healthy competition."

G. W. O. H.

The Development of Thermionic Valves for Naval Uses.*

By B. S. GOSSLING.

During the period of the war the thermionic valve passed through all the various stages of transition from an instrument whose operation was erratic and theory obscure to a product

* Abstract of paper read before the Wireless Section of the Institution of Electrical Engineers on June 23rd, 1920.

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as reliable and as standardised in manufacture as the incandescent lamp. The first four sections of this paper trace out the course of this transition as exemplified by the development of valves of various kinds by the wireless telegraphy department of H.M.S. *Vernon*, and later by H.M. Signal School, Portsmouth. They describe the introduction of valves into naval wireless telegraph installations and the early experimental and theoretical work in the elucidation of their observed behaviour. In the first place the valves were employed for the generation of low power oscillations for heterodyne reception. De Forest's ultraudion arrangement was first employed. The original audions were subsequently replaced by R.2, Q or R.4 valves as these were developed.

One of the first things observed in the study of well exhausted valves was that the anode and grid voltages are in a sense interchangeable and that in any formulæ they may always be associated together in an expression of the form $(e/m + e')$, where e is the anode voltage and e' the grid voltage. A formula was developed by Sir J. J. Thomson for the calculation of the valve constant m for the case of a cylindrical anode and a grid of parallel wires inside it:—

$$m = \frac{\pi N d' \log (d/d')}{\log [1/(\pi N d_0)]}$$

where d and d' are the anode and grid diameters respectively, and d_0 is the diameter of the grid wires which are spaced out N per centimetre round the circumference of the grid cylinder or as successive turns of a helix. In the French and many other later valves of cylindrical form the observed and calculated values of m agree to within about 10 per cent.

The fifth section of the paper treats with the design and development of power valves. For this purpose the following equation was taken as the basis of the design,

$$I = 2{\cdot}92 \times 10^{-5} \frac{l_f}{\beta^2 d'} \left\{ \frac{e/m + e'}{1 + 1/m} \right\}^{\frac{3}{2}}$$

where l_f is the length of the filament system measured along the axis of the concentric electrode cylinders. The values of the anode-current—grid-voltage slope k_1 and of the anode-current slope k_2 are then given by

$$k_1 = \frac{3}{2} \frac{I}{e/m + e'}; \qquad k_2 = k_1/m.$$

The design of the valve filaments was carried out by using the curves worked out by G. Stead.* As regards the heating of the anode it is stated in the paper that a radiation loss of about six watts per square centimetre may be allowed to keep within the limiting temperature for nickel. Numerical examples are given in the paper of the method of calculation, and also scale diagrams of two of the patterns of valve designed in that way and manufactured at the Osram-Robertson Lamp Works. Sections 6, 7 and 8 deal with the investigation and improvement of small valves for use in reception including both high-vacuum and gas-filled types. Successive stages of approximation in the calculation of characteristics of small valves with low operating voltages are illustrated in section 9, which includes a consideration of the effect of the temperature gradient near the ends of the filament. The final result of the calculation indicates the degree of closeness in which the observed behaviour of a high-vacuum valve can be accounted for in terms of known physical phenomena. The concluding section deals with the standardisation of valves and with their specification for quantity production, and refers to the various electrical tests that were applied to valves in order to secure a reasonable degree of uniformity.

As regards the gas-filled valves a number of experiments are referred to with different gases and at different pressures. In the case of the nitrogen-filled valves it was found that the gas gradually disappeared during the running of the valves. More satisfactory results were obtained with helium. In addition this gas does not cause disintegration of the filament as in the case of argon. For a given pressure a helium valve is much harder than a nitrogen valve, and for the same characteristics the pressure of helium required is about ten times the corresponding pressure of nitrogen. The best results were obtained with these valves by exhausting them as if they were to have a permanent high vacuum and then admitting the helium gas. By this process valves were obtained which were as constant throughout their life as the majority of high-vacuum valves.

* See RADIO REVIEW Abstract No. 635.

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Review of Radio Literature.

1. Articles and Patents.

580. ON UNDAMPED OSCILLATING SYSTEMS, AND IN PARTICULAR ON OSCILLATIONS SUSTAINED BY SELF-EXCITATION. A. Blondel. (*Journal de Physique*, 9, pp. 117—151, April, 1919, and pp. 153—162, May, 1919. *Science Abstracts*, 23A, p. 289, Abstract No. 742, May, 1920—Abstract.)

The author considers undamped oscillations under three headings:—(1) Self-sustained oscillations; (2) Oscillations consisting of a large number of partial discharges each generating a chain of damped oscillations; and (3) Oscillations produced by inversion of the driving force (series-wound dynamo and separately-excited motor). The present article deals only with the first class of oscillations and discusses these mathematically by the application of the Hurwitz method.* A number of polar diagrams are given illustrating the conditions existing in the case of Duddell and hissing arcs and oscillations sustained by triode valves.

581. VARIABLY COUPLED VIBRATIONS: GRAVITY-ELASTIC COMBINATIONS. MASSES AND PERIOD EQUAL. L. C. Jackson. (*Philosophical Magazine*, 39, pp. 294—304, March, 1920.)

This paper gives the mathematical theory of a coupled mechanical system which can be used as an analogy to the electrical case of circuits of equal inductance and frequency. The paper is illustrated with a number of curves of the oscillations of the system.

582. THE HIGH-FREQUENCY RESISTANCE OF WIRES AND COILS. G. W. O. Howe. (*Journal of the Institution of Electrical Engineers*, 58, pp. 152—170, February, 1920. *Electrical Review*, 86, pp. 25—26, January 2nd, 1920—Abstract. *Revue Générale de l'Électricité*, 7, pp. 791—794, June 12th, 1920. *Telegraphen- und Fernsprech-Technik*, 8, pp. 33—34, May, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 225—234, February, 1920, for abstract. Professor Howe's full reply to the discussion is included with the original paper in the *Journal of the I.E.E.*

583. HIGH-FREQUENCY MAGNETISATION. H. Fassbender. (*Science Abstracts*, 23A, p. 54, Abstract No. 157, January 30th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 96, January, 1920.

584. A COMPARISON OF COILS AND AERIALS FOR RECEPTION. M. Abraham. (*Electrical World*, 75, p. 687, March 20th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 72, December, 1919.

585. SOLID *v.* STRANDED WIRE FOR HIGH FREQUENCIES. W. Rogowski. (*Electrical World*, 75, p. 909, April 17th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 273, April, 1920.

586. A BEAT METHOD OF TESTING THE SLUGGISHNESS OF CONTACT DETECTORS. R. Ettenreich. (*Physikalische Zeitschrift*, 21, pp. 208—214, April 15th, 1920.)

The detector tested consisted of a fine nickelin wire in light contact with a crystal of galena. A circuit containing the detector was inductively coupled to two oscillating triodes. A wavemeter brought near the detector circuit indicated the two frequencies of these triodes and also the frequency of the beats. By working at wavelengths of 30 metres, the frequency of the beats was raised to five million cycles per second. The fact that these beats were

* See also RADIO REVIEW Abstract No. 419, June, 1920.

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indicated on the wavemeter without any diminution proves that the detector showed no sign of sluggishness. If the detector action is due to thermal effects, the heating and cooling must occur with this frequency—a highly improbable assumption.

587. STANDARDS OF HIGH FREQUENCY. A. Campbell. (*Electrician*, 84, p. 66, January 16th, 1920. *Science Abstracts*, 23A, pp. 164—165, Abstract No. 436, March 31st, 1920—Abstract.)

A method previously described by A. Dey, by which the oscillations of a pendulum can be maintained by an alternating current of very much higher frequency, is referred to, and it is suggested that the method might be applicable to the standardisation of radio frequencies. For instance a tuning fork of natural frequency, say 5,000, might be maintained by means of an alternating current of 50,000 or even 500,000 $\sim$.

588. MEASURING THE NATURAL WAVELENGTH OF AN ANTENNA. H. W. Houck. (*Everyday Engineering Magazine*, 8, pp. 318—319, February, 1920.)

The method described is very similar to an arrangement used in the French Radio Laboratories during the war. To carry out the test a small inductance is joined in series with the aerial and oscillations excited by joining a buzzer and cell in parallel with this inductance. The wavemeter is loosely coupled to the inductance and the wavelength measured for various numbers of turns in the circuit. By plotting the wavelength against the number of turns a straight line is obtained and from its intercept on the wavelength ordinate scale the fundamental of the aerial may be obtained. It is mentioned that a suitable coil for such measurements is wound with twenty-four turns of No. 12 B. & S. gauge* copper wire on a former 3 in. diameter by 3 in. long.

589. HIGH VOLTAGE, HIGH FREQUENCY APPARATUS AND ITS APPLICATIONS. F. P. Vaughan. (*Journal of the Engineering Institute of Canada*, October, 1919. *Technical Review*, 5, p. 180, November 25th, 1919.)

Various methods of generating high frequency currents are described, and a wiring diagram is also given of apparatus for experimental researches with these currents.

590. THE TELEPHONE RECEIVER: ITS MECHANICAL ACOUSTIC CHARACTERISTICS. W. Hahnemann and H. Hecht. (*Elektrotechnische Zeitschrift*, 41, p. 378, May 13th, 1920—Abstract.)

See RADIO REVIEW, 1, Abstract No. 405, June, 1920. The theory of the vibrating membrane is developed by replacing the mechanical quantities by their electrical equivalents. They find the efficiency of a receiver between 500 and 1,000 cycles per second to be from 0·1 to 1 per cent.

591. SOME APPLICATIONS OF TRIODES TO HIGH-FREQUENCY MEASUREMENTS. G. Leithauser. (*Verhandlungen der deutschen Physikalischen Gesellschaft*, 1, Series 3, pp. 23—28, March 31st, 1920.)

A communication from the Telegraphen-Versuchsamt describing (1) the use of a triode as a dynatron to maintain oscillations in a wavemeter, (2) the use of an oscillating triode to determine the natural frequency of a circuit with which it is loosely coupled, (3) the measurement of signal strength by an amplifier operating a galvanometer through a barretter bridge, (4) the measurement of small capacities by beats between two oscillating triodes; the unknown capacity being added to the capacity of one of the triode circuits.

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* Approximately the same as No. 14 S.W.G.

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592. THE SHORTEST WAVES PRODUCED WITH VACUUM TUBES. H. Barkhausen and K. Kurz. (*Physikalische Zeitschrift*, 21, pp. 1—6, January 1st, 1920.)
See editorial article in RADIO REVIEW, 1, p. 435, June, 1920.

593. THE COMPARISON OF INDUCTANCES AND CAPACITIES BY AN ELECTROMETER METHOD. A. W. Smith. (*Science Abstracts*, 23A, p. 53, Abstract No. 154, January 30th, 1920—Abstract.)
See RADIO REVIEW Abstract No. 104, January, 1920.

594. ON SOME EXPERIMENTS IN WHICH TWO NEIGHBOURING MAINTAINED OSCILLATORY CIRCUITS EFFECT A RESONANT CIRCUIT. J. H. Vincent. (*Proceedings of the Physical Society of London*, 32, pp. 84—91, February 15th, 1920. *Science Abstracts*, 23A, p. 240, Abstract No. 612, April, 1920—Abstract.)
See RADIO REVIEW, 1, pp. 285—287, March, 1920, for abstract.

595. SPARK GAP FOR IMPULSE EXCITATION. C. Lorenz. (*German Patent* 299098, March 22nd, 1917. Patent published, October 7th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 245, March, 1920—Abstract.)
An arrangement of plate electrodes between which the *optimum* amount of ionisation can be maintained. The ionisation may be produced either by heating the electrodes or by allowing ultra-violet light, Röntgen or Becquerel rays to impinge on the plates.

596. ROTARY DISCHARGER. W. D. Owen. (*Radiograph*, 1, pp. 185—187, June, 1920.)
A brief *resumé* of the advantages of the rotary spark gap over the fixed spark gap, and of the method of adjusting the same to obtain a steady discharge.

597. A QUENCHED SPARK GAP. (*Wireless Age*, 7, p. 12, November, 1919.)
In the spark gap described the spark takes place between two concentric annular rings of metal so that its length remains constant and independent of variations of thickness of the insulating washers.

598. METHODS OF SIGNALLING WITH ARC TRANSMITTERS. H. L. d'E. Skipworth, H. A. Madge and H. Morris-Airey. (*British Patent* 142141, September 27th, 1916. Patent accepted, May 31st, 1917. Published May 27th, 1920.)
For the purposes of signalling with an arc radio transmitter it is proposed to connect two independent oscillatory circuits permanently across the arc, one of them being the aerial circuit and the other a closed circuit tuned to the same frequency. Signalling is effected by connecting a resistance in parallel with a part of the inductance in one or other of the circuits so as to control the expenditure of energy in those circuits. For the radiation of interrupted C.W. signals it is suggested that a commutator contact may be connected in place of the signalling key. A construction for the signalling key is given in which the contacts are enclosed in a hermetically sealed vessel which may be supplied with compressed or other gas to reduce the sparking of the contacts. The moving contact is controlled from outside by means of a solenoidal spring, the frame carrying the moving contact being attached to a flexible diaphragm.

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599. THE POULSEN ARC IN WIRELESS TELEGRAPHY. (*Electrical Review*, 86, pp. 423—426, April 2nd, 1920. *Science Abstracts*, 23B, p. 278, Abstract No. 548, May 31st, 1920—Abstract.)

This article briefly summarises without much technical detail the equipment used in various high-power arc wireless stations. It is illustrated with a number of photographs of the apparatus.

600. HOW TO BUILD ARC GENERATORS. H. W. Secor. (*Radio Amateur News*, 1, pp. 352—354, January, 1920.)

Constructional details are given of a ½ kW. water cooled enclosed arc set.

601. THE EFFECT OF DIRECT CONNECTION OF PLATE CIRCUITS WITH THE ANTENNA. (*Wireless Age*, 7, pp. 23—24, November, 1919. *Science Abstracts*, 23B, p. 170, Abstract No. 342, March, 1920—Abstract.)

The arrangement described is attributed to W. C. White. It is designed with a view to overcoming the disadvantage that when using direct coupling of the valve generator with the aerial, the filament batteries are not at earth potential. The recommended circuit diagram is indicated in Fig. 1. In this diagram the coils L_2 L_3 are very closely coupled. Tonic train transmission may be effected by shunting a buzzer contact across the coil L_3.

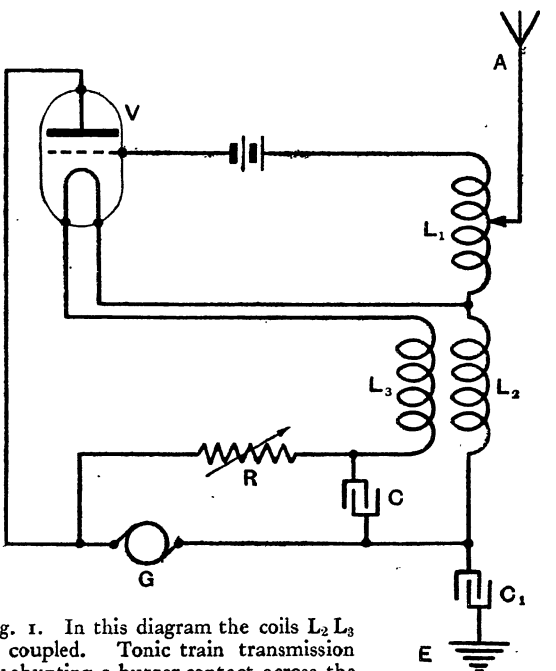

FIG. 1.

602. TRANSMITTING AND RECEIVING APPARATUS. L. de Forest. (*French Patent* 499661, May 25th, 1918. Published February 18th, 1920.)

This specification describes a system of radio signalling. For further particulars, see British Patent 131361.*

* RADIO REVIEW Abstract No. 121, January, 1920.

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603. APPARATUS FOR GENERATING HIGH-FREQUENCY OSCILLATIONS. F. Huth and S. Loewe. (*German Patent* 316793, November 14th, 1917. Patent published, October 7th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 79—80, January, 1920—Abstract.)

A valve circuit for the generation of oscillations in which the heating current for the filament is derived from the oscillatory current circuit.

604. A METHOD OF USING TWO TRIODE VALVES IN PARALLEL FOR GENERATING OSCILLATIONS. W. H. Eccles and F. W. Jordan. (*Revue Générale de l'Électricité*, 7, p. 24, January 3rd, 1920.)

See RADIO REVIEW, 1, pp. 80—83, November, 1919, for Abstract.

605. HIGH-FREQUENCY INDUCTOR ALTERNATORS. K. Schmidt; M. Osnos. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 154—158, February, 1920.)

A discussion on nomenclature and patent priority arising from a paper by Osnos on this subject.*

606. RADIO-FREQUENCY ALTERNATORS. W. Dornig. (*Elektrotechnische Zeitschrift*, 41, p. 420, May 27th, 1920.)

A criticism of a paper by Latour in the *Wireless World* of July, 1919.† Dornig regards machines for 30,000 cycles as "Wunderwerke der Technik," but considers it more practical and reliable to use machines for about 6,000 cycles with frequency transformers as at Nauen.

607. INSULATION OF ELECTRICAL MACHINES. C. Lorenz. (*German Patent* 298890, November 10th, 1916. Patent published, September 29th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 499, June, 1920—Abstract.)

A circuit for reducing the insulation necessary in electric machines, particularly high-frequency machines, in which the winding of the machine is divided and led to the primary winding of a transformer, the secondary of which is coupled to the antenna circuit.

608. STABILISING THE ENERGY OUTPUT OF TRANSMITTERS. (*Wireless Age*, 7, p. 20, November, 1919.)

The arrangement described, due to G. Reuthe, consists of a medium frequency alternator used in conjunction with three frequency multipliers. More stable results are claimed to be secured by de-tuning the intermediate circuits between the multipliers to a frequency higher than that corresponding to resonance.

609. TELEPHONE RECEIVERS FOR WIRELESS TELEGRAPHY AND TELEPHONY. (*Technical Review*, 6, p. 79, January 20th, 1920.)

It is announced that the Bureau of Standards, Washington, is conducting a comprehensive study of telephone receivers for radio work. It is probable that much other useful information will also be obtained as regards methods of measuring the strength of wireless signals.

610. TELEPHONE REPEATERS. B. Gherardi and F. B. Jewett. (*Electrician*, 84, pp. 517—519, 543—544, 571—575, 618—620, May 7th, 14th, 21st, and June 4th, 1920—Abstract. *Science Abstracts*, 23B, pp. 172—174, Abstract No. 348, March, 1920—Abstract.)

See RADIO REVIEW Abstract No. 228, March, 1920.

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* *Jahrbuch der drahtlosen Telegraphie*, 13, p. 270, November, 1918. Abstracted in *Wireless World*, 7, pp. 15—18, April, 1919.

† See also RADIO REVIEW, 1, p. 491, July, 1920.

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611. WIRELESS TELEPHONE TRANSMITTERS. L. B. Turner and R. H. Wagner. (*British Patent* 137098, December 24th, 1918. Patent accepted, January 8th, 1920.)

The transmitter described comprises a relatively feeble valve oscillator V_2 in which the amplitude of oscillation is controlled by the voice, and a valve amplifier V_3 serving to amplify

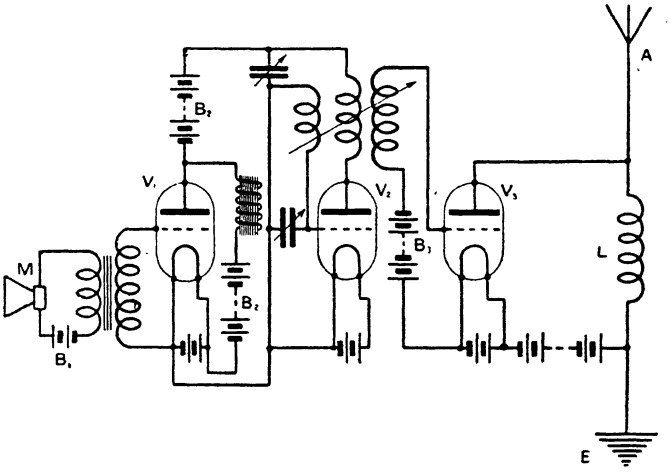

FIG. 2.

the voice controlled oscillations. The oscillations of V_2 may be modulated by the oscillation valve V_1 in the manner indicated using the "choke-control" method, or alternatively the microphone or the control valve may vary the grid potential of the oscillating valve. The voltage of B_3 is adjusted so that the grid potential of V_3 never becomes positive during transmission.

612. MICROPHONE CIRCUIT FOR LINE OR WIRELESS TELEGRAPHY. Allgemeine Elektrizitäts-Gesellschaft. (*German Patent* 300171, January 23rd, 1917. Patent published, September 24th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 161 — 163, February, 1920—Abstract.)

A modulation circuit for telephony in which the microphone M forms one arm of a Wheatstone bridge. With such an arrangement the ratio of the steady current to the telephone current through the modulating coil is independent of the ratio of the steady current to the telephonic current through the microphone itself. Fig. 3 shows a scheme of connections for wireless telephony.

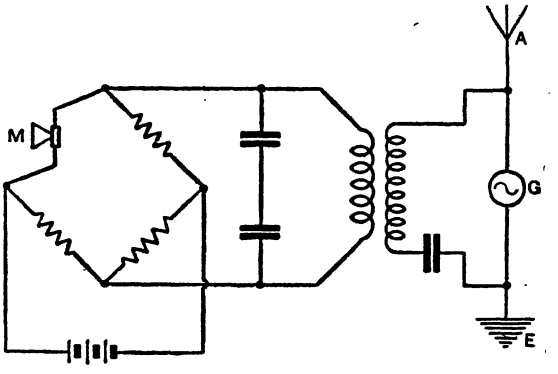

FIG. 3.

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613. MOUNTING TWO TRANSMITTERS IN PARALLEL. M. B. Sleeper. (*Everyday Engineering Magazine*, 8, p. 319, February, 1920.)
An illustration is given of a simple mounting for two ordinary pattern microphone transmitters to enable them to be used in parallel for radiotelephony. Both transmitters are spoken to simultaneously.

614. NEW WIRELESS TELEPHONE. (*Journal of the American Institute of Electrical Engineers*, 39, p. 176, February, 1920.)
Note *re* tests of a radiotelephone outfit over ranges up to 900 miles using $\frac{1}{3}$ kW., and working through considerable interference. See also Abstract No. 618.

615. A MARCONI WIRELESS TELEPHONE CABINET. (*Electrical Review*, 86, p. 350, March 12th, 1920. *Science Abstracts*, 23B, p. 280, Abstract No. 551, May 31st, 1920—Abstract.)
A brief illustrated description of a new $\frac{1}{2}$ kW. cabinet set. Daylight telephony range = 100 nautical miles (or 300 miles for C.W. telegraphy). The constant-current "choke" control method of modulation is indicated in the circuit diagram.

616. WARTIME ADVANCE IN WIRELESS TELEPHONY. (*Nature*, 105, p. 145, April 1st, 1920.)
A brief reference to a demonstration at Chelmsford of wireless telephony and direction finding on a Handley Page aeroplane.

617. WIRELESS TELEPHONY. (*Electrical Review*, 86, p. 145, January 30th, 1920. *Telegraph and Telephone Age*, 38, p. 18, January 1st, 1920.)
Relates to an installation of wireless telephone apparatus by the Public Electric Supply Co., N. Illinois.

618. WIRELESS TELEPHONY. (*Electrical Review*, 86, p. 688, May 28th, 1920.)
Refers to recent wireless telephony tests by the de Forest Radio Company, New York, over 1,500 miles using only $\frac{1}{3}$ kW. at the transmitter. See also Abstract No. 614.

619. WIRELESS TELEPHONY TESTS. (*Electrical Review*, 86, p. 336, March 12th, 1920.)
Refers to reports of successful radiotelephone tests between Berlin and Sweden (435 miles), and Berlin and Moscow (1,060 miles).

620. MULTIPLEX RADIOTELEPHONY. (*Scientific American*, 122, p. 481, May 1st, 1920.)
Refers to a demonstration of multiplex radiotelephony using different frequencies on a single antenna. No technical details are given.

621. A RADIOTELEPHONE TRANSMITTER. M. B. Sleeper. (*Everyday Engineering Magazine*, 8, pp. 222—224, January, 1920.)
An illustrated description of a simple form of valve radiotelephone transmitter.

622. WIRELESS TELEPHONY ON AEROPLANES. C. E. Prince. (*Journal of the Institution of Electrical Engineers*, 58, pp. 377—390, May, 1920; also abstracts in *Times Engineering Supplement*, No. 544, p. 89, February, 1920. *Nature*, 105, pp. 55—56, March 11th, 1920. *Electrical Review*, 86, pp. 441—442, April 2nd, 1920. *Electrician*, 84, pp. 448—449, April 23rd, 1920. *Technical Review*, 6, p. 341, April 13th, 1920. *L'Elettrotecnica*, 7, p. 329, June 25th, 1920.)
See RADIO REVIEW, 1, pp. 281—283 and 341—342, March and April, 1920, for abstract.

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623. DUPLEX WIRELESS TELEPHONY. P. P. Eckersley. (*Nature*, 105, p. 154, April 1st, 1920—Abstract. *Technical Review*, 6, p. 384, April 27th, 1920—Abstract.)
See RADIO REVIEW, 1, pp. 338—340, 383—385, April and May, 1920, for abstract.

624. DUPLEX WIRELESS TELEPHONY AND SELECTIVE RECEPTION. E. F. W. Alexanderson, (*Electrical Review*, 84, p. 681, May 28th, 1920—Abstract.)
See RADIO REVIEW Abstract No. 75, for the original paper.

625. HIGH-SPEED WIRELESS TRANSMISSION. (*R.E. Journal*, 21, p. 60, February, 1920. *Electrical Review*, 86, p. 240, February 20th, 1920—Abstract. *Technical Review*, 6, p. 263, March 16th, 1920—Abstract.)

Reference is made to some experiments which are said to have been in progress for some time at the Signals Experimental Establishment, Woolwich, relative to high speed reception. It has been found quite practicable to handle wireless traffic at speeds up to 100 words per minute, using punched tape transmission and Wheatstone inker reception. The received message could also be used to operate a Creed printer or a land line transmitter, thus permitting direct coupling of the wireless with the land lines.

626. APPARATUS FOR MODULATING HIGH-FREQUENCY OSCILLATIONS. E. F. Huth. (*German Patent* 307192, December 23rd, 1917. Patent published, October 4th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 159, February, 1920—Abstract.)

A method of modulating the electrical oscillations of a triode generator on aircraft in which electrical impulses derived from an alternating current siren attached to the shaft of the propeller, are communicated to the grid and filament of the triode.

627. INTERESTING KEY CONTROLS. W. Dornig. (*Elektrotechnische Zeitschrift*, 41, pp. 367—368, May 13th, 1920.)

A description of several methods of signalling. In one system the key operates relays which cut inductance out of one circuit and put inductance in another circuit thereby tuning the working circuit and de-tuning a dummy circuit or *vice versâ*. In another system two transformers have their primaries in series but their secondaries in the aerial and dummy circuits respectively. By means of relays auxiliary primary windings are so connected in one or other of the transformers that the main primary is exactly neutralised. Normally the aerial transformer is neutralised but on depressing the key the dummy transformer is neutralised and the aerial transformer made operative. The object throughout is to maintain a steady load on the generators and thus avoid the change of speed with load.

628. RADIO RELAY STATIONS. Western Electric Company, U.S.A. (*British Patent* 142371, July 29th, 1919. Patent accepted, May 6th, 1920.)

In order to avoid reaction between the transmitting and receiving apparatus at a radio station employed for automatically relaying a message from one station to another it is proposed to arrange the transmission from the station to be on a different wavelength from the signals that are received. This change in wavelength may be effected by combining the incoming signal with a heterodyne oscillation of a different frequency; thus if the carrier wave of the incoming signal is of frequency N_1 and is modulated with a speech or signal frequency of n, the resultant frequency of the incoming signals will vary between $N_1 + n$ $N_1 - n$. It is proposed that this incoming signal shall be combined at the relay station with an oscillation of frequency N_2 so that the resultant frequencies will then vary between $N_1 + N_2 + n$ and $N_1 + N_2 - n$ and also between $N_1 - N_2 + n$ and $N_1 - N_2 - n$. These currents may be passed through amplifier circuits tuned to either the higher or lower ranges of frequency so that the output from the transmitting side of the relay station takes place with a carrier wave frequency of either $N_1 + N_2$ or $N_1 - N_2$. In the case of a series of such relay stations one station may be arranged to raise the frequency of carrier waves and the next one to lower it again.

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629. A NEW THERMIONIC VACUUM TUBE. J. Scott-Taggart. (*Electrical Review*, 86, pp. 261—262, February 27th, 1920. *Science Abstracts*, 23B, p. 223, Abstract No. 436, April, 1920—Abstract.)

A special form of experimental tube is described in this note. The filament (tungsten) is 25 mm. long mounted vertically in the bulb. The plate is 10 mm. × 10 mm. × 0·008″ nickel sheet mounted 9 mm. away from the filament. The control electrode is also in the form of a plate (22 mm. × 10 mm. × 0·008″ nickel sheet) mounted parallel to the plate electrode but on the opposite side of the filament and 2 mm. away from it. Some characteristic curves are given. These are of the same general type as for a normal triode, but when the potential on the control electrode is positive and greater than about two volts the anode current curves begin to bend over. Eventually saturation is reached and for greater potentials the current falls, as the control plate is more easily able to absorb electrons than the usual wire grid. The tube makes a good amplifier and detector, the latter property being especially good at the point of maximum anode current—since then both half waves of the oscillation cause a decrease of the anode current.

630. A NEW THERMIONIC VALVE. S. R. Mullard. (*Electrical Review*, 86, p. 330, March 12th, 1920.)

Correspondence relative to an article by J. Scott-Taggart with the above title, and referring to some experimental valves made up by the writer to Dr. J. Erskine-Murray's design which give similar characteristics.

631. VACUUM TUBES. General Electric Company, U.S.A. (*British Patent* 142207, February 7th, 1919. Patent accepted, May 6th, 1920.)

This patent deals with the construction of triode valves of the flat plate type. The most important feature described relates to the winding of the grid around a rectangular frame in the interior of which the filament is stretched. The sides of the frame are wound with a spiral of fine wire so that the turns of the grid wire may be evenly spaced between turns of the side spirals thus maintaining an even spacing for the grid wires.

632. VALVE CONSTRUCTION. Osram-Robertson Lamp Works, Ltd. (*French Patent* 499871, August 30th, 1918. Published February 25th, 1920.)

This specification relates to the arrangement of the support for the electrodes in ionic tubes, more particularly for wireless telegraphy. A cylindrical electrode is supported at each end by a set of longitudinally extending bars attached to elastic fingers, which are sprung into a recess at the junction of the bulb with its neck. The elastic fingers are held distended by a locking-ring. In the form illustrated in the patent the elastic fingers consist of blade springs which are bent back towards the anode and double on themselves to form clips for securing the locking-ring, and they may be riveted to sockets fitting carrier bars for the electrode.

For further particulars of the invention, see British Patent 119088.

633. VALVE CONSTRUCTION. Osram-Robertson Lamp Works, Ltd. (*French Patent* 499872, August 30th, 1918. Published February 25th, 1920.)

The invention described in this specification relates to an ionic tube, such as is used in wireless telegraphy. A cylindrical anode is supported at each end by longitudinally extending pliable fingers which have outward bends which engage a shoulder at the junction of the bulb with its neck. The said fingers are pressed outwards against the next by an expanding spring ring which may be seated in kinks in the fingers.

For further particulars, see British Patent 119089.

634. THE THEORY OF VALVE RECTIFICATION. W. S. Barrell. (*Wireless World*, 7, pp. 181—186, 244—246, 337—340, July—October, 1919. *Telegraphen- und Fernsprech-Technik*, 8, pp. 185—188, February, 1920—Abstract.)

The theory of rectification in a two-electrode and in a three-electrode valve is discussed.

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635. THE SHORT TUNGSTEN FILAMENT AS A SOURCE OF LIGHT AND ELECTRONS. G. Stead. (*Journal of the Institution of Electrical Engineers*, 58, pp. 107—117, January, 1920. *Science Abstracts*, 23A, p. 242, Abstract No. 617, April, 1920—Abstract.)

The experiments described in this paper were carried out in the Cavendish Laboratory during the early part of 1918 to provide data for the design of tungsten filaments for thermionic valves for use in the Navy. In the introduction Langmuir's experiments on the variation of the physical properties of tungsten with temperature are discussed and it is then pointed out that the factors which determine filament voltage, emission (and candle power), for pure tunsgten are: filament length, filament diameter, filament temperature, and the cooling of the ends of the filament by the leads. In this paper the following symbols are used: I_f, E_f, R_f, W_f, l_f, d_f, P_f, and i, for the filament current, voltage, resistance, watts, length, diameter, candle power, and emission respectively. Comparing two filaments of different diameters working at the same temperature, and including end corrections:—

The filament currents are in the ratio of the 3/2 powers of the diameters.

The voltages per centimetre are in the inverse ratio of the square roots of the diameters.

The resistances per centimetre are in the inverse ratio of the squares of the diameters.

The watts per centimetre are proportional to the diameters.

The emissions per centimetre are proportional to the diameters.

A determination was made of certain characteristics of the tungsten filament as functions of the diameter. Some of these are shown in Fig. 4. In this figure the symbols used have the meanings already given or those stated under the figure.

The distribution of temperature along the tungsten filament in the neighbourhood of one of the leads was determined by means of an optical pyrometer which was mounted on a cathetometer in front of a bulb containing a long "hairpin" filament. This was done for a series of maximum temperatures, and by combining the results with those previously obtained for a uniform filament a series of end correction curves was obtained for voltage, electron emission, etc. These are given in Fig. 5. The procedure for designing a filament to produce a given electron emission when the overall voltage is given, and the filament diameter is provisionally chosen, is then worked out. Several examples are given in the paper illustrating the method of procedure. The method is an accurate one, but is rather laborious as it involves a certain amount of trial and error and interpolation between calculated results.

The case is also considered for a very short filament when the end correction overlaps the "central" part of the filament so that the maximum temperature at the middle does not reach its normal value that it would have if the filament were longer, and it is shown that this design can also be proceeded with in the manner previously outlined.

The paper concludes with an approximate method for the more rapid design of filaments. The results obtained are generally accurate within a few per cent. for filament temperatures between 2,000° K. and 2,500° K. and for filament diameters between 0·0035 cm. and 0·012 cm. The object of the method is, first, to find the overall voltage which would be necessary if the whole filament were as hot as the middle part; the filament length can thus be found at once from the $E_f\sqrt{d_f}/l_f$ curve (Fig. 4). Next the length is found of a filament which gives the same emission as the actual filament and whose temperature is everywhere the same as that of the central portion of the actual filament. The emission can then be found from the $i/l_f d_f$ curve in Fig. 4.

The procedure may be summarised as follows:—

FILAMENT LENGTH.

(*a*) Subtract 300 from the absolute temperature of the central portion of the filament, multiply the result by 4, and divide by 10,000.
(*b*) Subtract filament diameter in cms. from 0·0088 cm. and multiply the result by 100.
(*c*) Subtract (*b*) from (*a*) and add the result to the required overall voltage.
(*d*) Find E_f/l_f from Fig. 4 and divide it into the result of (*c*). This gives the required filament length.

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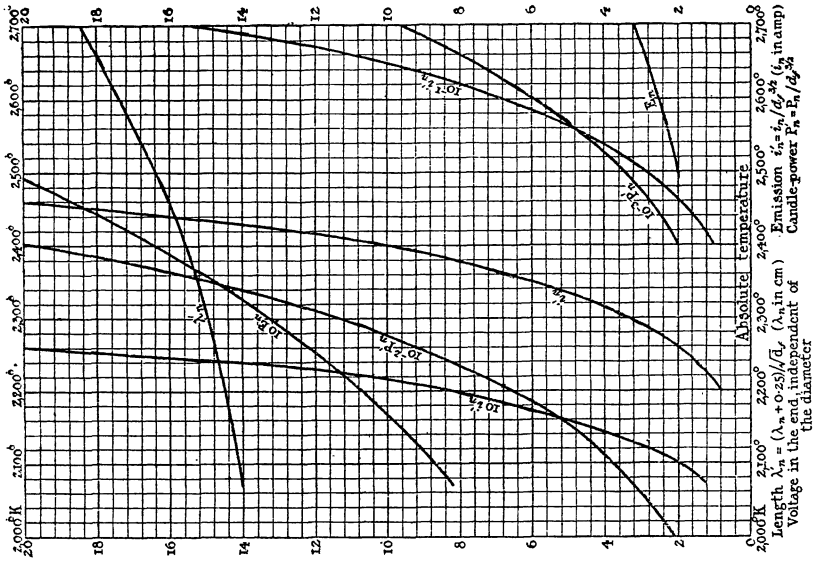
Absolute temperature
Length $\lambda'_n = (\lambda_n + 0{\cdot}25)/d_f$ (λ_n in cm)
Voltage in the end independent of the diameter
Emission $i'_n = i_n/d_f^{4/3}$ (i_n in amp)
Candle-power $P'_n = P_n/d_f^{3/2}$
d_f always in centimetres

FIG. 5.

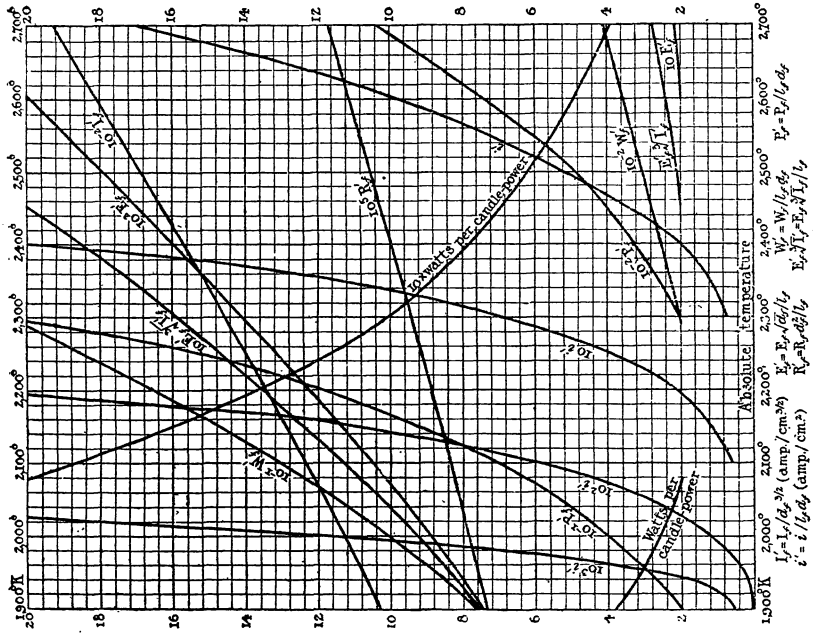

FIG. 4.

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EMISSION.

(*e*) Multiply the length of the end λ_n (obtained from the λ_n' curve of Fig. 5) by 1·20 and subtract the result from the length of the filament found in (*d*). Call the result *l'*.

(*f*) Find the emission *i* corresponding to *l'* by means of the *i'* curve in Fig. 4.

The following example is chosen from amongst those given in the paper to illustrate the above approximate method:—

Design of a 4-volt filament of diameter 0·0058 cm., temperature of central portion 2,390° K.

(*a*) $(2{,}390 - 300) \times 4 \times 10^{-4} = 0{\cdot}8160$.

(*b*) $(0{\cdot}0088 - 0{\cdot}0058)\ 100 = 0{\cdot}30$.

(*c*) $(0{\cdot}8160 - 0{\cdot}30) + 4$ volts $= 4{\cdot}516$.

(*d*) From Fig. 4, $E_f/l_f = 2{\cdot}073$ using the $E_f\sqrt{d_f}/l_f$ curve, then $4{\cdot}516/2{\cdot}073 = \underline{2{\cdot}18}$ cm. = filament length.

(*e*) $\lambda_n' = 15{\cdot}5$, $\therefore \lambda_n = 0{\cdot}92$; $0{\cdot}92 \times 1{\cdot}20 = 1{\cdot}10$; $2{\cdot}18 - 1{\cdot}10 = 1{\cdot}08 = l'$.
$\therefore i/l_f = 10{\cdot}3$; $\therefore i = 10{\cdot}3 \times 1{\cdot}08 = \underline{11{\cdot}1}$ milliamps.

636. THE DESIGN OF TRIODE GENERATOR CIRCUITS. M. Vos and R. Ziegler. (*Science Abstracts*, 23B, pp. 162—163, Abstract No. 327, March, 1920—Abstract.)
See RADIO REVIEW Abstract No. 292, April, 1920.

637. THE DESIGN OF MULTIPLE STAGE AMPLIFIERS USING THREE ELECTRODE THERMIONIC VALVES. C. L. Fortescue. (*Journal of the Institution of Electrical Engineers*, 58, pp. 65—82, January, 1920. *Radio Amateur News*, 1, pp. 344—345, January, 1920—Abstract. *Science Abstracts*, 23B, pp. 221—222, Abstract No. 433, April, 1920—Abstract.)

Paper read at a wireless sectional meeting of the Institution of Electrical Engineers, see RADIO REVIEW, 1, pp. 178—181, January, 1920, for abstract.*

Some further discussion (communicated) from Professor E. W. Marchant, as well as Professor Fortescue's reply are also included in the original.

638. AN INVESTIGATION OF THE EFFECTS OF ELECTRON COLLISIONS WITH PLATINUM AND WITH HYDROGEN. F. Horton and A. C. Davies. (*Proceedings of the Royal Society*, 97A, pp. 23—43, March, 1920. *Nature*, 104, p. 618, February 5th, 1920—Abstract.)

639. TRIODE VALVES AS ELECTRIC AMPLIFIERS. W. H. Eccles. (*Nature*, 104, pp. 501—502, January, 1920. *Science Abstracts*, 23B, p. 221, Abstract No. 432, April, 1920—Abstract.)

This article briefly describes the nature and properties of triode valves and indicates the magnitudes of the current, voltage, and energy amplifications that are obtainable with such valves. The article is particularly devoted to indicating the manner in which such valves may be employed for magnifying very low frequencies or steady potential differences. The resistance coupled amplifier arrangement devised in the French military radiotelegraphic laboratory is described and the simplified connection of this using common filament and high tension batteries is also given. It is shown that when the anode circuit resistances are about 80,000 ohms and taking average values for the valve constants, that the potential magnification of the single valve may be about 7·5, and with two valves about 56. A connection scheme due to the author is also given in the article in which each valve forms one arm of a balanced Wheatstone bridge. With this circuit arrangement the magnification obtainable is of the same order as with the French arrangement when the balancing bridge arm resistances are taken at the same values as the anode resistances in the previous arrangement.†

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* See also RADIO REVIEW Abstract No. 355, May, 1920.

† See also RADIO REVIEW Abstract No. 237, March, 1920, where very similar arrangements are described by A. Blondel.

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640. ELECTRON DISCHARGE TUBES AND THEIR APPLICATIONS. P. Letheule. (*Le Génie Civil*, 76, pp. 199 *et seq.* All issues between February 21st, 1920, and March 20th, 1920; also May 1st to June 5th, 1920. *Technical Review*, 6, p. 342, April 13th, 1920—Abstract.)

A very detailed description of vacuum tube apparatus and phenomena, with many references to early work on the subject. The following are the main headings: Elster and Geitel, Edison Effect, Fleming Valve, Richardson, Langmuir, Coolidge, Kenotron, Tungar, Audion, Oscillating Audion, Production of Very High and Very Low Frequencies, Heterodyne and Endodyne Reception, Amplification, Lieben and Reisz, Pliotron, Dynatron, Pliodynatron.

641. APPLICATIONS OF AMPLIFYING VALVES. L. Bloch. (*Revue Scientifique*, 58, pp. 12—19, January 10th, 1920. *Nature*, 104, pp. 647—648, February 12th, 1920—Abstract.)

A general article dealing with the industrial applications of amplifying valves. Reference is made to their use for telephonic relays, rectifiers, wireless amplifiers and receivers, earth telegraphy, and oscillation generators.

642. THE VACUUM TUBE. P. H. Boucheron. (*Scientific American*, 122, pp. 64—65, January 17th, 1920.)

A general article describing three-electrode valves and various circuits for use with them.

643. PRACTICAL OPERATION OF THERMIONIC DETECTORS. H. J. van der Bijl. (*Popular Science Monthly*, 96, pp. 130—140, February, 1920.)

A general article summarising the various modes of operation of triode detectors when receiving damped and continuous waves.

644. STRUCTURE AND OPERATION OF THE VACUUM VALVE. R. W. A. Brewer. (*Journal of Electricity*, 44, pp. 102—105, February 1st, 1920. *Electrical World*, 75, p. 744, March 27th, 1920—Abstract.)

The writer brings out some of the features upon which depend the uniformity of vacuum valves based upon extensive experiences in testing.

645. THERMIONIC VACUUM TUBE AS DETECTOR, AMPLIFIER AND GENERATOR OF ELECTRICAL OSCILLATIONS. W. H. Eccles. (*Electrician*, 84, pp. 522—524, May 7th, 1920. *Engineering*, 109, pp. 724—725, May 28th, 1920.)

Abstracts of two lectures delivered at the Royal Institution. A general summary was given of the properties of two and three-electrode valves, which were illustrated by a number of experiments. The use of the tubes in cascade amplifiers and for heterodyne work was also discussed, as well as a number of novel applications of such valves, including the indication of very minute changes in the specific inductive capacity of a dielectric.

646. WHO INVENTED THE VACUUM TUBE? T. A. Edison; P. H. Boucheron. (*Scientific American*, 122, p. 185, February 21st, 1920.)

Correspondence relative to the first publication of the discovery of the Edison effect (a paper by E. J. Houston before the American Institute of Electrical Engineers, October, 1884, is quoted), and of Dr. Fleming's share in its application to radio work.

647. ON THE THREE-ELECTRODE VALVE. P. Trichard. (*Revue Générale de l'Électricité*, 7, p. 178, February 7th, 1920.)

Correspondence relative to the paper by Dr. W. H. Eccles and F. W. Jordan on the use of two triode valves in parallel for generating oscillations.* The writer claims that the arrange-

* RADIO REVIEW, 1, pp. 80—83, November, 1919.

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ment described is a particular case of the more general arrangement described in his French Patents of September 6th, 1918 (Frequency multiplier), and September 13th, 1918 (Generator of high frequency current), and also in his British and U.S. applications of August, 1919.

648. "THE THERMIONIC VALVE AND ITS DEVELOPMENT IN RADIOTELEGRAPHY AND TELEPHONY." L. de Forest. (*Electrician*, 84, p. 226, February 27th, 1920.)

Further correspondence relative to the book with the above title. See also RADIO REVIEW, 1, pp. 259—261, February, 1920.

649. "THE THERMIONIC VALVE AND ITS DEVELOPMENTS IN RADIOTELEGRAPHY AND TELEPHONY." M. Latour; J. A. Fleming. (*Electrician*, 84, pp. 41—42, January 9th, 1920.)

Correspondence relative to the book by J. A. Fleming with the above title*; see RADIO REVIEW, 1, pp. 259—261, February, 1920; also M. Latour (RADIO REVIEW, 1, pp. 367—368, April, 1920), and RADIO REVIEW Abstracts Nos. 648, 650.

650. "THE THERMIONIC VALVE AND ITS DEVELOPMENTS IN RADIOTELEGRAPHY AND TELEPHONY." J. Scott-Taggart. (*Electrician*, 84, p. 66, January, 1920.)

Further correspondence relative to Dr. Fleming's book with the above title. See also RADIO REVIEW, 1, pp. 259—261, February, 1920, and pp. 367—368, April, 1920; also RADIO REVIEW Abstracts Nos. 648 and 649.

651. THERMIONIC VALVES ON AIRCRAFT. R. Whiddington. (*Nature*, 104, p. 630, February 12th, 1920.)

Correspondence relative to the variation of wavelength of oscillations set up by triodes by variations of the filament current and plate voltage. Reference is also made to a recent paper by Drs. W. H. Eccles and J. H. Vincent (see RADIO REVIEW Abstracts Nos. 503, July, 1920, and 655, August, 1920).

652. NAVY VACUUM TUBE COLLECTION. (*Popular Science Monthly*, 96, p. 144, February, 1920.)

Photographs and particulars are given of thirty-eight different patterns of triode vacuum tubes.

653. WHAT THE DE FOREST AUDION HAS DONE AND WHAT IT MAY YET DO. C. H. Claudy. (*Scientific American*, 122, p. 540, May 15th, 1920.)

A brief *resumé* of Dr. de Forest's work in the development of the audion.

654. TECHNICAL DEVELOPMENT OF THERMIONIC TRANSMITTERS. L. Kühn. (*Elektrotechnische Zeitschrift*, 41, p. 141, February 12th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 295, April, 1920.

655. FURTHER EXPERIMENTS ON THE VARIATION OF WAVELENGTH OF THE OSCILLATIONS GENERATED BY AN IONIC VALVE DUE TO CHANGES IN FILAMENT CURRENT. J. H. Vincent. (*Proceedings of the Royal Society*, 97, pp. 191—196, April 15th, 1920. *Nature*, 105, p. 121, March 25th, 1920—Abstract. *Chemical News*, 120, p. 165, April 1st, 1920—Abstract.)

It has previously been found that the wavelength of the valve oscillations is a function of the filament current.† This paper studies the effect more in detail. Special rheostats

* See review in RADIO REVIEW, 1, pp. 156—159, December, 1919.

† See RADIO REVIEW Abstract No. 503, July, 1920; also pp. 481—489, July, 1920.

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were designed to avoid change of inductance of the filament circuit when varying the filament current. It is suggested that changes in several of the variables of a valve-maintained circuit produce effects of the same sign in the wavelength and amplitude of the oscillations ; the wavelength and amplitude decrease with decrease of grid voltage or of plate voltage ; they also decrease when the coupling of the grid coil with the main oscillating coil decreases ; increasing the resistance in either the condenser or the inductance branch of the main oscillating circuit lessens the amplitude and wavelength, while altering the filament current in either direction from that giving the maximum wavelength gives also a decreased amplitude.

656. ABSORPTION OF GASES IN THE ELECTRIC DISCHARGE TUBE. F. H. Newman. (*Proceedings of the Physical Society of London*, 32, pp. 190—195, April 15th, 1920. *Chemical News*, 120, p. 166, April 1st, 1920—Abstract.)

The paper describes a method of showing that absorption of nitrogen takes place in the discharge tube when sodium and potassium are used as the electrodes. The amount of gas absorbed increases with the temperature.

In the discussion Professor Fortescue commented upon the possibility of some of the electrode films having absorbed gases when exposed to the atmosphere, and on the different effects of positive and negative ions.

657. DISCHARGE IN HIGH VACUUM. J. E. Lilienfeld. (*Annalen der Physik*, 61, pp. 221—263, February, 1920.)

By using long cylindrical tubes with various distances between the electrodes the author finds a linear fall of potential along the discharge in confirmation of his previous results with exploring electrodes. The author sees in his results a proof of the absence of space charge and of the insufficiency of the 1·5 power law criterion of the quality of the vacuum.

658. MEASUREMENTS ON VACUUM TUBES. H. G. Möller. (*Archiv. für Elektrotechnik*, 8, pp. 46—58, July 15th, 1919. *Electrical World*, 75, p. 687, March 20th, 1920—Abstract.)

A number of laboratory methods are outlined in this paper. To overcome difficulties arising from current inequalities at the ends of the filament when comparing different triodes the author suggests that the plate current be adjusted to a prescribed value rather than the filament current. An emission of 4 mA. per watt of heating power is recommended.

659. MEASUREMENT OF THE CHIEF PARAMETERS OF TRIODE VALVES. W. H. Eccles. (*Proceedings of the Physical Society of London*, 32, pp. 92—104. February 15th, 1920.)

See RADIO REVIEW, 1, pp. 283—285, March, 1920, for abstract. The original also contains additional discussion by Professor A. O. Rankine relative to the use of triodes for amplifying thermo-electric e.m.f.'s.

660. A COMPARATIVE METHOD OF TESTING THERMIONIC VALVES FOR PASSING NO REVERSE CURRENT AT HIGH VOLTAGES. N. W. McLachlan. (*Proceedings of the Physical Society of London*, 32, pp. 72—77, February 15th, 1920.)

See RADIO REVIEW, 1, pp. 239—240, February, 1920, for abstract.

661. A METHOD OF MEASURING THE AMPLIFICATION OF A RADIO FREQUENCY AMPLIFIER. F. W. Jordan. (*Proceedings of the Physical Society of London*, 32, pp. 105—115, February 15th, 1920.)

See RADIO REVIEW, 1, pp. 288—289, March, 1920, for abstract.

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662. ON THE MEASUREMENT OF AMPLIFICATION GIVEN BY TRIODE AMPLIFIERS AT AUDIBLE AND AT RADIO FREQUENCIES. F. E. Smith and H. C. Napier. (*Proceedings of the Physical Society of London*, 32, pp. 106—132, February 15th, 1920.)

See RADIO REVIEW, 1, pp. 287—288, March, 1920, for abstract. The original also contains additional discussion by Mr. P. R. Coursey.

663. STANDARD VACUUM TUBE NOTATIONS IN GERMAN LITERATURE. (*Electrical World*, 75, p. 687, March 20th, 1920—Abstract. *Telegraphen- und Fernsprech-Technik*, 8, p. 58, July, 1919.)

See RADIO REVIEW, 1, p. 437, June, 1920, for full particulars of the proposed symbols.

664. ELECTROLYTIC RECTIFICATION. G. Schulze. (*Zeitschrift für Instrumentenkunde*, 40, p. 98, May, 1920.)

A brief abstract from the annual report of the Reichsanstalt (March, 1920), stating that the investigation had been resumed especially with regard to aluminium rectifiers using very pure aluminium. The points under investigation are :—Rate of formation, sparking voltage, maximum voltage, thickness of oxide film and of gas film, the remanent current and the minimum voltage in the conduction direction.

665. THE WAVE FORM OBTAINED FROM AN ALUMINIUM RECTIFIER. N. H. Williams and J. M. Cork. (*Science Abstracts*, 23B, p. 27, Abstract No. 55, January 30th, 1920. *Electrical Review*, 86, p. 682, May 28th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 358, May, 1920.

666. THE GENERATION OF HIGH TENSION DIRECT CURRENTS. M. Schenkel. (*Science Abstracts*, 23B, pp. 28—29, Abstract No. 56, January 30th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 117, January, 1920.

667. DIRECTIONAL WIRELESS SIGNALLING. F. A. Kolster. (*British Patent* 137069, December 24th, 1919. Convention date, March 31st, 1916. Patent not yet accepted but open to inspection. *Wireless Age*, 7, pp. 24—25, November, 1919 — Abstract. *Science Abstracts*, 23B, p. 165, Abstract No. 333, March, 1920 —Abstract.

The subject-matter of this patent deals with direction finding with two or more frame aerials. The use of two coils crossing one another at any angle is claimed, the coils being connected in series and tuned by one or more variable condensers in the usual manner. Directions are determined by observation of the position of minimum signals. A special modification indicated in Fig. 6 is also described. The two receiving coils A and B enclose the metal gauze capacity areas indicated. The gauze is connected to one terminal of the coil and a double thermionic valve detector is used in the manner shown.

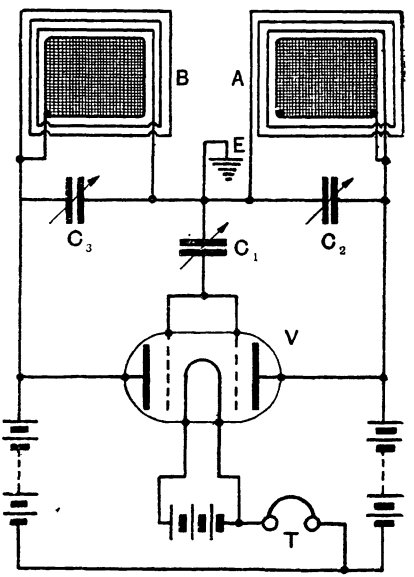

FIG. 6.

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For the determination of distance as well as direction an arrangement is described of two pairs of crossed coil receivers placed at the ends of a base line of known length. The coils may be rotated by distant controls from a central observation station.

668. WIRELESS TELEGRAPHY AND AERIAL NAVIGATION. Franck. (*L'Aéronautique* 1, pp. 291—295, December, 1919. *Technical Review*, 6, p. 177, February 17th, 1920—Abstract.)

The author makes a plea for the organisation of radiogoniometric stations, and after explaining the principles of wireless direction finding, points out the advantages of the installation of such stations at definite points. The system of stations could be used for aerial navigation during fog.

669. DIRECTION FINDING. J. Robinson. (*French Patent* 500003, May 24th, 1919. Published February 28th, 1920.)

Apparatus for finding the direction of Hertzian waves described in this specification, is of the kind in which two vertical coils are arranged at an angle to each other and are rotatable about a vertical axis. For further particulars, see British Patent 134560.*

670. WIRELESS DIRECTION FINDER. J. Robinson. (*British Patent* 134560, May 27th, 1918. Patent accepted, May 9th, 1919. Patent published, December 11th, 1919.)

The method of direction finding set out in this specification is that customarily known as the "R.A.F. Crossed-coil method" which has been fully described by the same author.†

671. A METHOD OF DIRECTION FINDING OF WIRELESS WAVES AND ITS APPLICATION TO AERIAL AND MARINE NAVIGATION. J. Robinson. (*Science Abstracts*, 23B, p. 220, Abstract No. 429, April, 1920—Abstract. *Technical Review*, 6, p. 302, March 30th, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 213—219, February, 1920, and pp. 265—275, March, 1920, for original paper.

672. ON THE HISTORY OF DIRECTION FINDING AT THE DÖBERITZ AND LÄRZ AERODROMES. R. Baldus, E. Buchwald and R. Hase. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 99—101, February, 1920.)

See Abstract No. 673 which also deals with this article.

673. DIRECTIONAL WIRELESS ON AEROPLANES. E. Buchwald and R. Hase, (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 101 and 113. February, 1920. *Technical Review*, 6, p. 384, April 23rd, 1920—Abstract. See also RADIO REVIEW Abstract No. 672.)

A report of experiments carried out for the military authorities at Döberitz and Lärz. The aeroplane carried a trailing receiving aerial coupled to an antenna circuit containing a barretter inserted in one arm of a Wheatstone bridge. The aerial current was determined from the deflection of the galvanometer. Long dashes were sent from a fixed station with a wavelength of 250 metres. The exact position and direction of the aeroplane at the moment of reading was determined by taking a photograph of the ground immediately below by means of a camera fitted into the floor of the aeroplane. Curves are given showing the variation of received current as the aeroplane approached, passed over and receded from the transmitting station, and also showing the effect for a given distance of the rotation of the plane about a vertical axis.

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* RADIO REVIEW Abstract No. 670.

† RADIO REVIEW, 1, pp. 213—219, February, 1920, and pp. 265—275, March, 1920.

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674. EXPERIMENTS WITH SCHELLER'S RADIO COURSE SETTER ON AEROPLANES. E. Buchwald. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 114—122, February, 1920. *Technical Review*, 6, pp. 384—385, April 27th, 1920—Abstract.)

German Patent No. 201496 of 1907 described two horizontal sending aerials enclosing an angle, connected alternately to the sending apparatus, which is sending a long dash. If one aerial sends out the letter A the other will send the inverse, viz., N. A receiving station which bisects the angle between the two sending aerials will hear a long dash, others will hear either A or N or both with different intensities. The present article describes experiments with aeroplane reception and compares the results with calculations made by Burstyn. The results are very complicated in view of the vertical angle subtended by the aeroplane at the sending station and by the varying direction of the receiving antenna which hung freely from the aeroplane.

675. THE ELECTROMAGNETIC PLANE-WAVE IN TWO MEDIA. K. Uller. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 123—152, February, 1920. *Technical Review*, 6, p. 885, April 27th, 1920—Abstract.)

A highly mathematical investigation of the transmission of a plane wave along the boundary between two media. The author considers the terms "surface wave" and "space wave" introduced by Sommerfeld to be unfortunate and misleading. The author appears to favour reflection rather than refraction, but is not clear on this point.

676. ON THE ABSORPTION OF CORPUSCULAR RAYS PENETRATING THE TERRESTRIAL ATMOSPHERE AND FOLLOWING NON-RECTILINEAR PATHS. C. Störmer. (*Comptes Rendus*, 170, pp. 742—744, March 22nd, 1920.)

A mathematical treatment of the paths followed by ionised particles entering the earth's atmosphere under the influence of the earth's magnetic field, as affecting the ionisation produced in the upper atmosphere by these particles.

677. AN ION-PRODUCING EFFECT IN THE UPPER ATMOSPHERE. W. Hammer. (*Physikalische Zeitschrift*, 21, pp. 218—219, April 15th, 1920.)

The interplanetary space may contain a large number of molecules and the collisions between these and the earth's atmosphere due to the earth's orbital velocity may produce ionisation.

678. WIRELESS TELEGRAPHY AND TELEPHONY. W. H. Eccles. (*Electrician*, 84, p. 296, March 12th, 1920.)

Correspondence relative to the theoretical derivation of the Austin-Cohen transmission formula. The author points out that if as the distance between the stations increases the wavelength be varied so as always to produce the required signal intensity with the least possible value of the product Ih, then Ih must be proportional to the cube of the distance (I being the sending aerial current and h the sending aerial height); and also that the power required for signalling varies approximately as the sixth power of the range.

See also RADIO REVIEW Abstract No. 679.

679. WIRELESS TELEGRAPHY AND TELEPHONY. R. C. Colwell. (*Electrician*, 84, p. 526, May 7th, 1920.)

Further discussion * relative to the derivation of the transmission formula.

680. THE RANGE OF WIRELESS STATIONS. R. C. Trench. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 494—526, October, 1919. Article abstracted from *Electrician*, 79, pp. 102, 147 and 181, 1917.)

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* See RADIO REVIEW Abstract No. 678.

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681. THE CONDITIONS FOR LONG RANGE IN WIRELESS. Professor Demanet. (*Union des Ingénieurs de Louvain*, 46, pp. 128—136, 1919.)

This paper presented before the Society in 1914 and only just published owing to wartime difficulties, summarises the chief factors influencing the range of wireless stations. The first part summarises the influence of the capacity, insulation, wavelength, etc., of the aerial, while the second briefly reviews the different means for the production of damped and undamped waves. The treatment given is based upon the following formula for the energy picked up by the receiving aerial at a distance D from the transmitter :—

$$W_2 = W_1 \left(\frac{3}{4}\right)^2 \left(\frac{\lambda^2}{2\pi}\right)^2 \frac{1}{D^2} \epsilon^{-2AD/\sqrt{\lambda}}$$

where W_1 = power of the transmitter, λ = the wavelength and A = absorption coefficient.

682. WIRELESS IN SUBMARINES. (*La Nature*, 48, pp. 17—19, January 10th, 1920.)

A brief account of the use of loop aerials under water for reception on submerged submarines. Experiments with the arrangement described were commenced in 1917 by Lieut. de Broglie in French submarines. Two loop aerials are used mounted outside the submarine and fixed at an angle of 40° to one another, so that by connecting them in series or parallel or using them singly reception can be secured from any direction. A seven-valve amplifier was used. The American arrangement using a large single turn loop of which the submarine shell forms one side is also mentioned.

683. IMPROVEMENT IN VALVE MOUNTINGS. Gesellschaft für drahtlose Telegraphie. (*German Patent* 299776, May 3rd, 1917. Patent published September 29th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 257, March, 1920—Abstract.)

A scheme of preventing valve noises in which the movement of the filament is damped mechanically by springs.

684. NEW DETECTOR AND AMPLIFIER UNITS. (*Everyday Engineering Magazine*, 8, p. 235, January, 1920. *Radio Amateur News*, 1, p. 335, January, 1920.)

An illustrated description of a panel type valve detector and amplifier manufactured by the International Radio Co.

685. A SYSTEM FOR THE RECEPTION OF CONTINUOUS WAVES. J. Scott-Taggart. (*Telegraph and Telephone Age*, 39, pp. 62—64, February 1st, 1920. *Science Abstracts*, 23B, p. 168, Abstract No. 339, March, 1920—Abstract.)

Paper read before the Wireless Society of London. See RADIO REVIEW, 1, pp. 181—183, also RADIO REVIEW Abstract No. 434, June, 1920.

686. HETERODYNE RECEPTION. A. Meissner and E. Scheiffler. (*Zeitschrift für Fernmeldetechnik*, Nos. 2 and 3, 1920.)

An experimental study of heterodyne reception of both damped and undamped waves using both crystal and audion detectors. The audibility was determined with different values of local current for the same signal current, and also for different signal currents using always the optimum local current. The description is somewhat unsatisfactory owing to the absence of detailed explanation. The parallel-ohm method was employed, but what precautions were taken to avoid erroneous results are not stated. Up to a certain point the audibility was found to be roughly proportional to both the received and local currents, but the latter reached an optimum value beyond which the audibility was practically independent of the local current. It is stated that good tone and amplification due to heterodyne action can be obtained with quenched spark signals if proper adjustments are made.

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687. WAVEMETER WITH CAPACITY BRIDGE. F. Kock. (*Physikalische Zeitschrift*, 21, pp. 214—216, April 15th, 1920.)

A description of a compact instrument for army field work, consisting of a wavemeter with buzzer carborundum detector and telephone, together with a set of ratio arm resistances, so that capacities of aerials, etc., can be measured by the bridge method. Range 60—8,000 metres and capacities of 50—200,000 cms.

688. THE OSCILLATORY VALVE RELAY: A THERMIONIC TRIGGER DEVICE. L. B. Turner. (*Journal of the Institution of Electrical Engineers*, 57, Supplement, pp. 50—65, April, 1920. *Technical Review*, 6, p. 548, June 22nd, 1920—Abstract.)

Paper read at a Wireless Sectional Meeting of the Institution of Electrical Engineers, June 30th, 1919. The principle of the relay is dealt with in RADIO REVIEW Abstract No. 196, February, 1920.* Various modifications for special purposes are described in the original paper, which also includes a report of the discussion.

689. DIFFERENTIAL VALVE RELAYS. L. B. Turner. (*British Patent* 142333, June 4th, 1919. Patent accepted, May 6th, 1920. *Engineer*, 129, p. 613, June 11th, 1920.)

The essential features of the arrangement described are indicated in Fig. 7. Two triode valves V_1 V_2 are connected up with the common filament battery V_1 and H.T. battery B_2 so that their plate circuits include the windings of the differential relay R. The plate currents traverse the winding R in opposite directions so that their resultant effect may be balanced

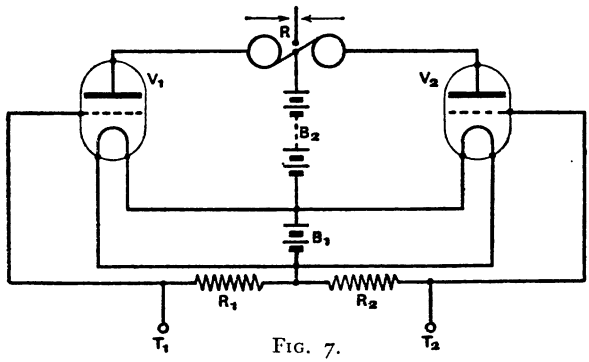

FIG. 7.

out in their normal condition. The grid circuits of the valves include resistances R_1, R_2 across which the incoming signal is applied by means of the terminals T_1, T_2. The passage of a current through the resistance R_1 R_2 upsets the balance of the valves and causes the relay to operate. Alternatively the resistance R_1 R_2 may be replaced by the secondary winding of a differential transformer through the primary of which the incoming signal is passed.

690. RECORDING OF EIFFEL TOWER TIME SIGNALS FOR DETERMINATION OF CLOCK ERROR. L. B. Turner. (*Electrical World*, 75, p. 687, March 20th, 1920—Abstract. *Science Abstracts*, 23A, p. 261, Abstract No. 666, May 31st, 1920—Abstract.)

See RADIO REVIEW Abstract No. 244, March, 1920.

691. THE PRINCIPLE OF THE ATMOSPHERIC ELIMINATOR. W. E. Cragor. (*Model Engineer*, 42, pp. 385—386, May 20th, 1920.)

A selective receiver is described to eliminate atmospherics and jamming. The apparatus

* See also RADIO REVIEW Abstracts No. 244, March, 1920, and No. 690, August, 1920.

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depends upon acoustic tuning of diaphragms under the influence of an electromagnet through which the signals are passed.

692. A PORTABLE SET, AND SOME PROPERTIES OF C.W. SETS. R. C. Clinker. (*Wireless World*, 7, pp. 712—721, March, 1920. *Engineer*, 129, p. 394, April 16th, 1920—Abstract. *Everyday Science*, 2, p. 110, June, 1920—Abstract. *Technical Review*, 6, p. 385, April 27th, 1920—Abstract. *Electrical Review*, 86, p. 505, April 16th, 1920—Abstract. *Electrician*, 84, p. 406, April 9th, 1920—Abstract.)

An illustrated description of a compact portable wireless receiver manufactured by the British Thomson-Houston Co., Ltd., and described by R. C. Clinker at a meeting of the Wireless Society of London.*

693. THE PORTAPHONE. (*Scientific American*, 122, p. 571, May 22nd, 1920.)

A brief illustrated description of a portable receiver containing its own loop aerial inside the case.

694. THE WEAGANT GROUP FREQUENCY CIRCUIT. (*Wireless Age*, 7, pp. 16—20, November, 1919.)

In the circuit described a single valve is used with the telephones tuned to the group frequency.

695. THE PRACTICAL CONSTRUCTION OF WIRELESS RECEIVING STATIONS. P. Maurer. (*L'Électricien*, 50, pp. 6—10, January, 1920.)

This article deals with constructional details of the various parts of small receiving stations for experimental use.

696. CRYSTAL AND VACUUM TUBE DETECTORS. E. M. Sargent. (*Radio Amateur News*, 1, pp. 355—356, January, 1920.)

A comparison of the mode of operation of these detectors, by consideration of their characteristics.

697. STRAIGHT DETECTION *versus* THE OSCILLATING TUBE. (*Scientific American*, 122, p. 157, February 14th, 1920.)

Briefly refers to a report of a test carried out by the U.S. Naval Aircraft Radio Laboratory with a view to comparing simple detection plus amplification, with a receiver using an oscillating valve. The latter arrangement is favoured, particularly for radio-compass work, in spite of the loss of individuality in the case of spark signals.

698. AERIAL ARRANGEMENTS FOR WIRELESS SIGNALLING. F. A. Kolster. (*British Patent* 137073, December 24th, 1919. Convention date, November 27th, 1916. Patent not yet accepted but open to inspection.)

The essential feature of the radiating circuit described lies in the separation of the inductance and capacity of the aerial instead

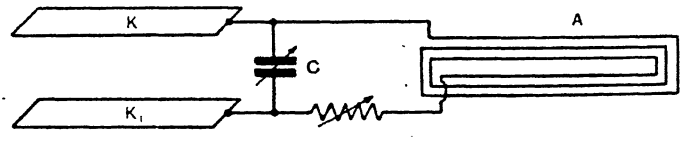

FIG. 8.

* See RADIO REVIEW, 1, pp. 292—293, March, 1920; also RADIO REVIEW Abstract No. 527, July, 1920.

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of their being jointly distributed as in the ordinary arrangement. The arrangement described is practically an ordinary frame aerial with a variable condenser for tuning purposes and excited by a spark or arc transmitter. For directional purposes the aerial system may be arranged as in Fig. 8, in which the inductance takes the form of the elongated loop A and the capacity that of the elongated pair of capacity areas K K_1. An additional variable condenser C may be added for tuning purposes. Radiation is a maximum in the plane of the coil and plates.

699. DESIGNING AN AMATEUR TRANSMITTING ANTENNA. E. T. Jones. (*Radio Amateur News*, 1, p. 358, January, 1920.)

Curves of fundamental wavelength are given for aerials of various heights and spans.

700. NOTES ON RADIO ANTENNAS. (*Everyday Engineering Magazine*, 8, pp. 229—230, January, 1920.)

A brief summary of the chief properties of ordinary antennæ, loop aerials, and condenser aerials.

701. ANTENNÆ. J. Hettinger. (*French Patent* 498983, May 1st, 1917. Published January 28th, 1920.)

The invention consists in the use, as transmitting and receiving aerials for wireless telegraphy and telephony, of beams of ionised air, such as searchlight beams containing ultra-violet rays. It is also proposed to use such beams as electrically-conductive connections between fixed or movable stations. A single beam, projected by an arc or mercury-vapour lamp enclosed in a quartz vessel, is used as a transmitting aerial, and is connected through an electrode and spark gap to earth in the usual way, the aerial being coupled directly or inductively to the producing or receiving circuits. If desired two or more beams, either parallel or converging, may be employed, the two beams being produced by a single source by means of reflecting plates. The arc or spark gap in the oscillation circuit may be used as the source of ultra-violet rays. The electrode connecting the beam with the wire leads may be a grid lying across the beam or a series of spaced concentric cylinders with their axis along the beam, or a plurality of pointed spikes or projections with spaces between. Other forms are also described. The electrode for reflecting the beam consists of a metallic plate having a number of small reflecting surfaces, the surface facing away from the source of the beam being highly polished or covered with metal such as rubidium or an alloy of potassium and sodium which is highly sensitive to the photo-electric effect. The other face is covered with or formed of a metal which is only slightly sensitive, such as copper. The ionised beam may be combined with metallic aerials and may be partly or wholly saturated by direct current or alternating current of low frequency. The oscillations are then superimposed thereon.

For further particulars see British Patent 124833, also RADIO REVIEW Abstract No. 702.

702. A HIGH ANTENNA WITHOUT HIGH MASTS. J. Hettinger. (*Wireless Age*, 7, pp. 21—23, November, 1919. *Science Abstracts*, 23B, p. 170, Abstract No. 341, March, 1920—Abstract.)

The use of beams of ultra-violet light to ionise the air is suggested for obtaining a convenient elevated antenna.

703. A NEW FORM OF WIRELESS AERIAL. (*Electrical Review*, 86, p. 367, March 19th, 1920.)

Refers to some experiments at Scheveningen on a form of earth aerial.

704. WIND EFFECTS IN TOWER DESIGN. R. Fleming. (*Engineering News-Record*, 83, pp. 640—664, October 2nd, 1919. *Science Abstracts*, 23B, p. 17, Abstract No. 34, January 30th, 1920—Abstract.)

This paper summarises American practice with regard to the design of various towers to resist wind. The treatment includes towers for wireless aerials.

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705. IMPERIAL WIRELESS COMMUNICATIONS. (*Electrical Review*, 86, p. 337, March 12th; pp. 377—379, March 19th, 1920. *Electrician*, 84, p. 283, March 12th, 1920. *Engineer*, 129, p. 280, March 12th, 1920. *Telegraphen- und Fernsprech-Technik*, 8, p. 217, March, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraghie*, 15, pp. 515—516, June, 1920—Abstract. *L'Elettrotecnica*, 7, p. 170, April 5th, 1920. *Journal of the Franklin Institute*, 189, p. 606, May, 1920. *Technical Review*, 6, p. 385, April 27th, 1920—Abstract. *Science Abstracts*, 23B, pp. 278—279, Abstract No. 549, May 31st, 1920—Abstract.) See also PROPOSED IMPERIAL WIRELESS SYSTEM. (*Wireless World*, 8, pp. 41—43, April 17th, 1920. *Technical Review*, 6, p. 459, June 22nd, 1920—Abstract.)

Marconi's Wireless Telegraph Co., Ltd., have put forward to the Government their proposal for an Empire-wide wireless network. The proposed routes and branches are as follows:—

(1) England to India, and thence to Singapore, Australia and New Zealand, with a branch from Singapore to Hong Kong.
(2) England to Egypt, and thence to East Africa and South Africa.
(2A) England to Egypt, and thence to India, Singapore, etc.
(3) England to West Africa, and thence to South Africa; with a branch from West Africa to South America.
(4) England to West Indies.
(5) England to Montreal, and thence to Vancouver.
(6) Australia to Vancouver (only night service to begin with).

The use of C.W. transmission is recommended. Apparatus is already being assembled capable of dealing efficiently with an output of 100 kW. giving an aerial power of 75 kW. An aerial current of upwards of 300 amperes is expected.

The proposed aerial system for reception is that due to Franklin, an important characteristic of which is the absence of long horizontal aerial wires, which enables the various receiving systems to cross one another. The scheme of communications outlined depends fundamentally upon the adoption of the Franklin aerial.*

706. REVIEW OF TELEGRAPHY IN 1919. (*Journal Télégraphique*, 44, pp. 1—3, January 25th, 1920.)

Includes a list of recently opened routes of radiocommunication, and references to radiotelephone tests.

707. NOTES ON THE TELEFUNKEN SYSTEM. W. D. Owen. (*Radiograph*, 1, pp. 135—137, May, 1920.)

A brief illustrated description with circuit diagrams and particulars of various parts of a Telefunken installation captured during the war.

708. THE PRIESS LOOP SET: II. TRANSMITTER.† W. J. Henry. (*Radio Amateur News*, 1, p. 334, January, 1920.)

The set is excited from a 500 cycle power transformer operated from a 10 volt battery. The three turns of the transmitting loop are connected in parallel in order to obtain a low resistance. The article includes a wiring diagram and illustrations of the parts of the set.

709. A LIGHT-WEIGHT AIRPLANE TRANSMITTER. (*Everyday Engineering Magazine*, 8, pp. 228—229, January, 1920.)

An illustrated description of a ½ kW. set manufactured by the E. J. Simon Co.

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* See also pp. 543—544 of this issue.
† See also RADIO REVIEW Abstract No. 530, July, 1920.

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710. Radio Telegraph and Compass Service on the Coast in the Neighbourhood of New York Harbour. (*Telegraph and Telephone Age*, 38, pp. 17—18, January, 1920. *Aire, Mar y Tierra*, 2, pp. 43—44, January, 1920.)
Deals with the radio traffic control arrangements near New York (see Radio Review Abstract No. 203, February 1920).

711. Radiotelephony on Mount Hood. C. M. Allen. (*Radio Amateur News*, 1, p. 336, January, 1920.)
Describes an installation used in connection with the Forest Protective Service.

712. Christiania Wireless Station. (*Teknisk Ukeblad*, January 16th, 1920. *Technical Review*, 6, p. 177, February 17th, 1920—Abstract.)
A note to the effect that this station was officially opened on January 10th last. The installation works on the Arco system and is to be used exclusively for European messages, while the Stavanger station is reserved for American traffic.

713. Wireless Telegraphy in Caba Juby. (*Aire Mar y Tierra*, 2, pp. 17—21, January, 1920.)
A general description of the station.

714. Wireless Communication on the Lackawanna Railroad. (*Telegraph and Telephone Age*, 38, pp. 67—68, February 1st, 1920.)
A brief note relative to the resumption of radio work and experiments on the use of wireless on the trains of the Lackawanna Railroad Company. A number of illustrations of the installations are included.

715. Wireless and Everyday Business. B. F. Miessner. (*Scientific American*, 122, p. 182, February 21st, 1920.)
The applications of radiotelephony on the Lackawanna Railroad and elsewhere are dealt with.

716. Development of Wireless Telegraphy. (*Aire Mar y Tierra*, 2, pp. 55—56, January, 1920.)

717. The Wireless Era. (*N.P.L. Review*, 1, pp. 10—14, March, 1920.)
A general article describing briefly the triode valve and some of its applications.

718. Progress in the Art of Communication. B. Gherardi and F. B. Jewett. (*Electrical World*, 75, pp. 202—204, January 24th, 1920.)
Includes a very brief *resumé* of radio developments during 1919, in the three chief branches of Radiotelegraphy, Radiotelephony, and Radiogoniometry.

719. An Interesting Audion Control Box. M. B. Sleeper. (*Everyday Engineering Magazine*, 8, pp. 316—317, February, 1920.)
An illustrated description of a valve receiver manufactured by the Wireless Improvement Company (New York).

720. The Annual Physical Society and Optical Society Exhibition. (*Electrician*, 84, pp. 63—65, January 6th, 1920; pp. 117—119, January 30th, 1920; pp. 146—147, February 6th, 1920.)
Contains detailed descriptions of the electrical and wireless exhibits.*

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* See also Radio Review, 1, p. 240, February, 1920.

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721. STANDARDISATION OF ELECTRICAL INDICATING INSTRUMENTS FOR USE WITH RADIO APPARATUS. G. Y. Allen. (*Electrical Journal*, 16, pp. 494—500, November, 1919. *Science Abstracts*, 23B, p. 33, Abstract No. 65, January 30th, 1920.)

This paper describes with numerous illustrations the work carried out by the U.S. Navy in co-operation with various instrument-making firms towards standardising ammeters, voltmeters, etc., both for direct and alternating currents, and for high and low frequencies. The data includes constructional details of a special radio frequency ammeter with a bulb type of thermo-couple.

722. A 500,000-VOLT CONDENSER FOR TESTING PURPOSES. (*Electrical World*, 74, pp. 404—405, August 23rd, 1919. *Science Abstracts*, 23B, p. 33, Abstract No. 66, January 30th, 1920.)

This condenser has been designed for testing insulators for radio work. It is built for frequencies up to 60,000 cycles and is used in conjunction with a Poulsen arc. It is housed in a special hut outdoors.

723. ELECTRICAL WARNING SIGNALS FOR RAILWAY TRAINS. (*L'Électricien*, 50, pp. 145—149, April 15th, 1920.)

The Augereau system* of wireless communication with moving trains is described, together with a brief *resumé* of other experiments including wireless telephone communication tests with American trains, one of the latter installations being illustrated.

724. SOME DETAILS OF A NEW CONDENSER. M. B. Sleeper. (*Everyday Engineering Magazine*, 8, pp. 314—315, February, 1920.)

An illustrated description of a special form of vane type variable condenser designed to have great mechanical rigidity.

725. TEN-STEP VARIABLE INDUCTOR. (*Electrical World*, 75, p. 761, March 27th, 1920.)

A short note describing and illustrating a new variable inductance for H.F. circuits manufactured by the Clapp-Eastham Manufacturing Co.

726. THE WESTERN ELECTRIC CO.'S LOUD-SPEAKING TELEPHONE. (*Electrician*, 84, p. 300, March 12th, 1920. *Science Abstracts*, 23B, p. 224, Abstract No. 440, Abstract.)

Describes the constructional details of this new telephone and its use with amplifying valves.

727. MANUFACTURING DETAILS OF THE "B" BATTERY. (*Everyday Engineering Magazine*, 8, pp. 226—227, January, 1920.)

728. NEW APPARATUS FOR LIGHT TELEPHONY. H. Thirring. (*Physikalische Zeitschrift*, 21, pp. 67—73, February 1st, 1920.)

A description of improved apparatus developed in Germany during the war but too late to be employed at the front. The transmitter consisted of a searchlight upon the current of which is superposed the microphone current; the receiver consisted of a camera in which the beam is focussed on an improved selenium cell operating a telephone receiver through a four-stage amplifier. The difficulties arising in connection with various types of selenium cells and the troubles due to the self-excitation of the amplifiers are discussed. Even with a four-stage amplifier and a 35 cm. searchlight the range is only 8—9 km. The author entirely discredit's Ruhmer's claim to a range of 15 km.

* RADIO REVIEW Abstract No. 566, July, 1920.

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729. TELEGRAPHY AND TELEPHONY BY LIGHT RAYS. T. W. Case. (*French Patent* 499912, September 24th, 1918. Published February 26th, 1920.)

This specification describes a method of and apparatus for signalling by radiant energy. Light waves are utilised to vary a local current in accordance with a variation in the light waves produced at the sending station.

For further particulars, see British Patent 132341.*

730. PUTTING INFRA-RED RAYS TO WORK. G. Gaulois. (*Scientific American*, 122, p. 248, March 6th, 1920.)

A description of a photophone signalling arrangement using infra-red rays used during the war. A six-valve amplifier was used in conjunction with the receiver. Particulars of the filters for cutting out the visible rays from the transmitting searchlight are also given.

731. TELEPHONING BY LIGHT. A. O. Rankine. (*Nature*, 104, pp. 604—606, February 5th, 1920.)

A summary of early work, together with a description of the arrangements due to the author.†

732. THE TRANSMISSION OF SPEECH BY LIGHT. A. O. Rankine. (*Science Abstracts*, 23A, p. 52, January 30th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 178, January, 1920.

733. GERMAN AIRCRAFT RADIOTELEGRAPHY. E. Niemann. (*Jahrbuch der Drahtlosen Telegraphie*, 14, pp. 69—89, and 190—206, May and July, 1919. *Electrical World*, 75, p. 687, March 20th, 1920—Abstract.)

The article gives a description of a number of airplane stations for various purposes, and deals in detail with many practical questions.

734. FLYING OVER CLOUDS IN RELATION TO COMMERCIAL AERONAUTICS. M. Jones. (*Aeronautical Journal*, 24, pp. 220—249, May, 1920.)

The use of wireless telephony is discussed in connection with cloud flying in commercial aviation.

735. USE OF WIRELESS FOR PRESS PURPOSES. H. Bredow. (*Elektrotechnische Zeitschrift*, 41, pp. 75—76, January 22nd, 1920.)

A discussion from many points of view of the relative advantages and disadvantages of wireless and wire telegraphy for the distribution of news.

736. SOME DEVELOPMENTS IN THE ELECTRICAL INDUSTRY DURING 1919. J. Liston. (*General Electric Review*, 23, pp. 4—56, January, 1920.)

A short section on radio communication is included in this *resumé*. The 200 kW. Alexanderson alternator is dealt with particularly and the special regulator for maintaining constant speed is described. The high-frequency alternators are usually driven by 60 cycle induction motors fed from public power lines. One or more choke coils may be inserted in the supply line to the induction motor and the direct current saturation of these chokes controlled by means of a vibrating regulator of the ordinary power station type. The operation of the regulator is controlled by rectified current derived from a tuned high frequency circuit fed from the H.F. alternator.

737. A NEW POWERFUL WIRELESS COMPANY. (*Wireless Age*, 7, pp. 10—12, November, 1919. See also *Telegraphen- und Fernsprech-Technik*, 8, p. 33, May, 1920.)

Deals with the formation of the Radio Corporation of America.

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* RADIO REVIEW Abstract No. 320, April, 1920.

† See RADIO REVIEW Abstracts No. 178, January, 1920, No. 255, March, 1920, and No. 732.

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738. RADIOTELEGRAPHIC STATISTICS FOR 1918. (*Journal Télégraphique*, 44, pp. 22—28, February 25th, 1920.)
Gives numerous particulars (number of stations of various classes, number of messages, receipts, etc.) classified under the various countries of the world.

739. LOCATING UNDERGROUND PIPES AND CABLES WITH WIRELESS APPARATUS. M. Dieckmann. (*Elektrotechnische Zeitschrift*, 41, pp. 435—436, June 3rd, 1920.)
A quenched spark transmitter connected to a frame aerial and a detector and telephone receiver connected to another frame aerial are used as transmitter and receiver. The signals will be strongest when the two coils are over the pipe or cable.

740. WIRELESS SIGNALS ON LOCOMOTIVES. J. Trevieres. (*Le Génie Civil*, 76, pp. 391—394, April 24th, 1920.)
A description of a system under trial in France in which the movement of the signal closes a circuit and operates a wireless apparatus (Ruhmkorff coil and spark-gap) connected to an aerial alongside the track. The locomotive carries a receiving aerial and coherer by means of which a steam whistle is controlled.*

741. A RADIO RESEARCH BOARD. (*Nature*, 104, p. 638, February 12th, 1920. *Electrical Review*, 86, p. 209, February 13th, 1920.)
A list is given of the members of this Board which was recently established by the Department of Scientific and Industrial Research.

742. THE CONTROL OF WIRELESS TELEGRAPHY IN ENGLAND. (*Revue Générale de l'Électricite*, 7, p. 4B, January 3rd, 1920.)
Discusses the question of the undesirability of restricting "amateur" wireless activities.

743. X-RAY PHOTOGRAPHS OF RADIO APPARATUS. P. C. Rouls. (*Radio Amateur News*, 1, p. 688, June, 1920.)
The author refers to the use of X-ray photographs for rendering visible the arrangement of the wiring in the interior of radio apparatus. The method is particularly useful when the wiring is bedded in the interior of insulating panels.

744. USE OF RADIO BY TRANSMISSION COMPANIES. G. A. Iler. (*Electrical World*, 75, pp. 376—377, February 14th, 1920. *Science Abstracts*, 23B, p. 220, Abstract No. 430, April, 1920, Abstract.)
Illustrates the apparatus used by the Georgia Railway and Power Co. at their central and other stations. No trouble was experienced from the H.T. lines provided the aerials were arranged symmetrically with respect to the lines. The possible future use of wireless telephony is also discussed.†

745. TWO PHENOMENA DISCOVERED BY MEANS OF AMPLIFIERS. H. Barkhausen. (*Physikalische Zeitschrift*, 20, p. 401, September, 1919. *Elektrotechnische Zeitschrift*, 41, p. 379, May 13th, 1920—Abstract. *Wireless World*, 7, pp. 691—692, March, 1920—Abstract. *Technical Review*, 6, p. 342, April 13th, 1920—Abstract.)
If thin well-annealed iron is subjected to a steadily changing magnetising force, the E.M.F. induced in a coil gives noises in an amplifier, indicating sudden molecular movements. Peculiar sounds heard with amplifiers connected to earth wires are also mentioned.

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* See also RADIO REVIEW, 1, Abstracts No. 566, July, 1920, and No. 723.
† See also RADIO REVIEW Abstract No. 414, June, 1920.

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746. Alternating Current Amplifier. H. Könemann. (*German Patent* 303932, December 5th, 1916.)

An amplifier of alternating current consisting of a direct current arc with parallel oscillating circuits of different frequencies (Fig. 9). Sufficient resistance is included to bring the circuits to the verge of self-excitation in which case any impressed current oscillation may be amplified.

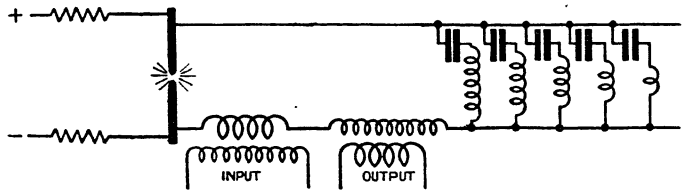

Fig. 9.

747. Cathode Ray Tubes. Gesellschaft für drahtlose Telegraphie. (*German Patent* 299103, March 21st, 1915. Patent published, September 11th, 1919. Addition to German Patent 298460. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 645, November, 1919—Abstract.)

A cathode ray tube for the amplification or generation of high-frequency oscillations in which the hot cathode of large surface consists of several parallel evenly spaced filaments which are connected electrically in parallel. The cathode and its connections lie in a plane which cuts the grid perpendicularly.

2. Books.

Radio Engineering Principles. By H. Lauer, B.S., and H. L. Brown, B.E.E. (New York: *McGraw-Hill Book Co., Inc.* London: *Hill Publishing Co., Ltd.* 1920. Pp. xv. + 300. Price 21*s.* net.)

This book is written by two former officers of the Signal Corps of the United States Army whose duties were "the preparation of training literature on radio theory and equipment." It contains, no doubt, the gist of a good deal of the literature thus prepared and is now published presumably for the consumption of the purely practical radio expert.

The whole field of modern wireless is covered in a descriptive manner with at intervals little outcrops of mathematics and extracts from recent papers and patent specifications.

According to the title page, the qualifications of the authors are unimpeachable, but after reading the book the conclusion is unavoidable that they do not understand the underlying principles of their subject. The book is full of statements which are either incorrect or misleading. These statements are distributed throughout the whole book and occur as frequently in the description of the action of specific pieces of apparatus as in the discussion of general principles. In many places, too, mere statements of facts are paraded in the guise of logical arguments.

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To take the individual chapters in order, the first is a refreshing attempt to break away from the usual dull *résumé* of electromagnetic theory found in the opening chapters of the majority of similar books. But it is disappointing to find it neither a logical statement of the modern electron theory nor a pleasantly readable account of the modern views of electricity.

Chapter II. deals with single and coupled oscillating circuits, and is perhaps a little more satisfactory than the first chapter. In Chapter III., the suspicion that arose when reading Chapter I., viz. that the authors do not understand the generally accepted theory of electromagnetic waves, becomes a certainty. Nor are they much happier in their description of the oscillations in an open earthed aerial.

Chapter IV. is the first chapter dealing with the application, and consists of a very passable account of the older damped-wave telegraphy, both transmitting and receiving. The usual methods are described and the advantages of loose-coupled receivers are well accentuated. Chapter V. corresponds to Chapter IV. but deals with the continuous-wave systems other than the valves. The essential features of the alternators and arcs are well described and heterodyne reception is dealt with fairly completely.

Chapter VI. contains a good general account of the three-electrode valve. The amplification factor of the valve is discussed at some length and its relation to the slopes of the characteristics worked out—albeit a little inconsistently at one or two points. Chapter VII. deals with the use of the valve for detecting. As in the majority of text books the detecting action with the grid insulating condenser is badly described. Chapter VIII. deals with amplifiers and on the whole is good. All the amplifier circuits of Figs. 147 and 148, 150, 152 and 153 have the anode battery shown on the valve side of the anode circuit. In practice the leakage and earth capacity of the battery would reduce the high-frequency amplification to a negligible amount with this arrangement. Also, separate batteries are shown for each valve. All this may be intentional, with a view to simplifying the explanations. But it is not stated that this is the case and the reader is led to suppose that this is the usual procedure. The claim for an amplification of 10^{14} for a seven-valve Signal Corps amplifier must surely be a record!

The ninth chapter deals with the valve as an oscillator, and is again quite good up to a point. It is noticeable that nothing—or practically nothing—is said of the limitations of output from a tube and the conditions prescribing these limits. Many circuits are described, but not at all from the practical point of view.

Radiotelephony, Chapter X., is quite well done. Here the authors are evidently more at home, but the following statement on the top of p. 254 gives one food for thought:—"During the travel of the waves through the æther from the transmitting to the receiving station, voice modulations of high frequency or pitch are absorbed to a greater extent than those of lower frequency."

Chapter XI. deals with direction finding and but for the now well-

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established impression that the authors do not understand the electromagnetic wave theory, might be very good indeed.

The last chapter gives a very short account of the application of wireless apparatus to special purposes such as aircraft, submarines, laboratory work, etc.

In spite of all these criticisms, this book has however one saving grace. Except in a few cases where very recent and untested apparatus is discussed (as for example on pp. 256 and 257) the perspective is essentially practical and up-to-date. Only those points are stressed which are of importance, and side issues are in general avoided. This is a merit not to be found in all books and will act as a counterpoise to some at any rate, of the defects mentioned. To the operator or amateur whose interests are purely practical and who does not desire the niceties of scientific accuracy this book may be recommended.

The printing and reproduction are in keeping with the usual high standard of the McGraw-Hill Co., and the number of mere printer's errors is no more than is to be expected in a first edition.

C. L. Fortescue.

Treatment of Harmonics in Alternating Current Theory by means of a Harmonic Algebra. By A. Press. (Berkeley, U.S.A.: *The University of California Press*. 1919. Pp. 66. Price $1.00.)

The object of this pamphlet is to give a mathematical discussion of the problem of wave-form in iron-cored inductances when an alternating current is applied to them. It is well known that owing to the saturation and hysteresis of such iron cores various higher harmonics appear in the current and flux wave-forms depending on the actual conditions. If it is assumed that the magnetising force, and therefore the magnetising current, is a pure sine wave the problem presents no difficulty; but unfortunately this is not the case which usually occurs. Generally the problem appears in the reverse form. The wave-form of the applied voltage and therefore of the resultant flux is known and it is required to deduce from this the current wave-form. In this form the problem has so far defied solution by mathematical means.

Mathematically this means that in the equation $B = \mu H$, μ is not a constant but a two-valued function of B.

The basis of the author's method is to introduce an operator function Q_m such that Q_m operating on $\sin pt$ produces $\sin mpt$. An operator calculus is thus derived by means of which this inverse operation is effected. The successive coefficients in the Fourier expansion of H are evaluated term by term, the algebra being fairly simple except in a few special cases. The method is applied to verify some results given by Hague and Neville in the *Electrician*, October 13th, 1916, but the discrepancies are rather large.

The special calculus is also applied to various other problems which arise

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in alternating current engineering such as the distribution of flux density in a mass of iron subjected to an alternating E.M.F. and formulæ are deduced for the power lost in such cases.

The work is not, of course, of special interest to the radio engineer whose use of iron cores is strictly limited; even when used they are worked at extremely low densities. It might, however, possibly come in in the design of control chokes for radiotelephony in connection with speech distortion.

J. HOLLINGWORTH.

LA TELEFONIA SENZA FILO. By Umberto Bianchi. (Milan: *Ulrico Hoepli*. 1920. Pp. viii. + 296. Price L. 10.)

A very unpretentious account of the development and present state of radiotelephony. No mathematical expression or symbol occurs in the whole volume and the book is evidently intended for a non-technical reader. It contains many inaccuracies, however, and one would hesitate to recommend it to such a reader. In addition to misleading descriptions of phenomena, one comes across such things as the following:—"un' energia primaria di 900 volts e una energia radiata di 300 watts," neither volts nor watts being units of energy. The book is profusely illustrated, but many of the photographs are very poorly reproduced.

G. W. O. H.

Books Received.

GRUNDRISS DER FUNKEN-TELEGRAPHIE IN GEMEINVERSTÄNDLICHER DARSTELLUNG. By Dr. Franz Fuchs. (Munich: *R. Oldenbourg*. Eleventh Edition. 1920. Pp. 73. Price 2.75 M.)

THE HOW AND WHY OF RADIO APPARATUS. By H. W. Secor. (New York: *Experimenter Publishing Co. Inc.* 1920. Pp. 160. Price $1.75.)

ETUDE DE QUELQUES PROBLEMES DE RADIOTÉLÉGRAPHIE. By H. de Bellescize. (Paris: *Gauthier-Villar et Cie.* 1920. Pp. 174. Price 16 fr.)

ÉLÉMENTS DE TÉLÉGRAPHIE SANS FIL PRATIQUE. By F. Duroquier. (Paris: *H. Dunod*. Second Edition. 1920. Pp. 130. Price 6 fr. 75.)

RADIOTÉLÉGRAPHIE PRATIQUE ET RADIOTÉLÉPHONIE. By P. Maurer. (Paris: *H. Dunod*. 1920. Pp. 386. Price 21 fr.)

A New French Radio Journal.

The first issue of a new French journal *Radioélectricité* has recently been published in Paris under the auspices of the *Revue Générale de l'Électricité*. This new monthly publication is addressed to all classes of radio workers and is to include technical and theoretical articles as well as more practical ones addressed to the experimenter and amateur. Special sections will be devoted to maritime and commercial information including matter of interest to ship wireless operators. A review of books and current periodicals is also to be included.

The Administrative Committee, under the presidency of M. J. Carpentier, includes the following engineers: MM. Brenot, Brylinsky, Dupont, Girardeau, de Valbreuze and Lezaud.

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THE

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THE
RADIO REVIEW

VOL. I SEPTEMBER, 1920 NO. 12

Electron Tube Generators of Alternating Currents of Ultra-Radio Frequencies.*

By G. C. SOUTHWORTH, M.S.

INTRODUCTION.

The electron tube amplifier when properly connected to a circuit containing inductance and capacity, will sustain continuous oscillations in that circuit. The tube merely provides the switching mechanism by which the energy from some source is used to maintain these oscillations. Its *rôle* is analogous to that of the escapement of a clock or the slide valve of a steam engine.

A general form of a generator circuit is shown in Fig. 1. The manner in which it operates may be explained briefly as follows: Variations in the plate current i_p, due to variations in the electron emission from the hot filament to the plate, cause a reactance drop across X_p. This institutes an E.M.F. in the oscillatory circuit $X_pX_oX_g$ which results in a current I_o. Variations in I_o create a reactance drop across X_g and impress a voltage on

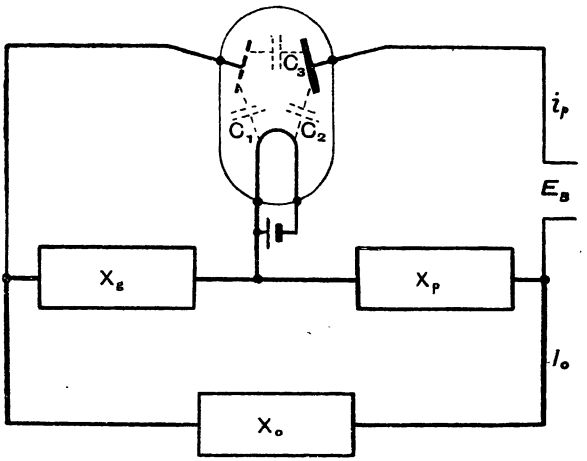

FIG. 1.—General form of Oscillating Circuit.

* Received April 30th, 1920.

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the grid. The variable grid voltage in turn causes variations in the plate current. This provides the conditions for continuous oscillations assuming that the connections give the proper phase relations. The power supply for sustaining these oscillations comes from the battery in the plate circuit.

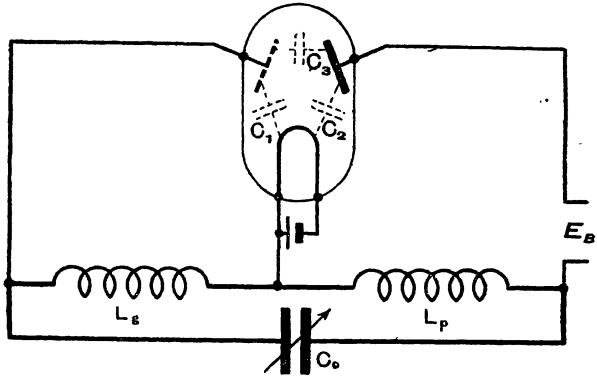

FIG. 2.—The "Hartley Circuit."

When X_p and X_g are inductive reactances and X_o is a capacitive reactance Fig. 1 reduces to the so-called "Hartley Circuit." If X_p and X_g are capacitive reactances and X_o is an inductive reactance, it reduces to the "Colpitt Circuit." In either case the frequency of oscillation is approximately that which makes $X_o + (X_p + X_g) = 0$.

APPLICATION TO THE HIGHER FREQUENCIES.

The electron tube generator is seldom used for frequencies higher than a few million cycles per second. Below this limit little difficulty is experienced, but at the higher frequencies difficulties of various kinds are encountered. The greatest of these are the necessarily small dimensions of the coils and condensers used, the uncertain distribution of the inductance and capacity

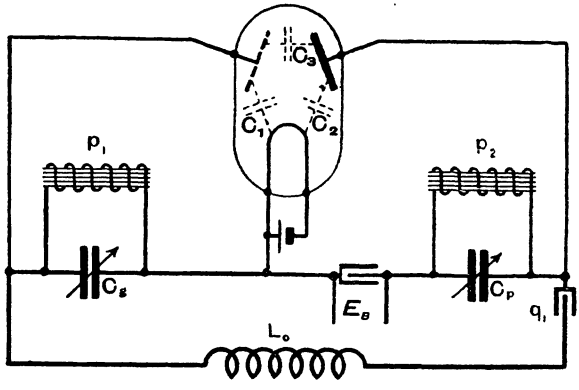

FIG. 3.—The "Colpitt Circuit."

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of connecting wires and instruments, and the relatively large capacities that exist between the electrodes of the tube. In view of these difficulties it is obvious that the Hartley Circuit in the form shown in Fig. 2 is not adaptable to wavelengths shorter than perhaps 50 metres since the tube capacities C_1, C_2 and C_3 may form circuits with the coupling inductances L_p and L_g whose natural periods limit the frequency and the power output.

The Colpitt Circuit which used capacitive reactances for coupling the tube to the circuit offers a great advantage inasmuch as the tube capacities do not ordinarily form resonant circuits with the coupling reactances. Its great disadvantage lies in the fact that numerous pieces of apparatus are required between which there may be extraneous capacities and weird coupling effects. The Colpitt connection in its usual form is shown in Fig. 3. The oscillatory circuit for the lower frequencies is indicated by the heavy lines. The choke p_2 completes the circuit for the direct current component of the plate current. The choke p_1 in conjunction with the large capacity q_1 serves to keep the grid and filament at approximately the same voltage. The design of the chokes is such as to make their reactance much greater than that due to C_g or C_p, and the natural period of the oscillatory circuit is not seriously altered by their presence. When all dimensions of this form of circuit are suitably reduced wavelengths as short as 20 metres may be obtained.

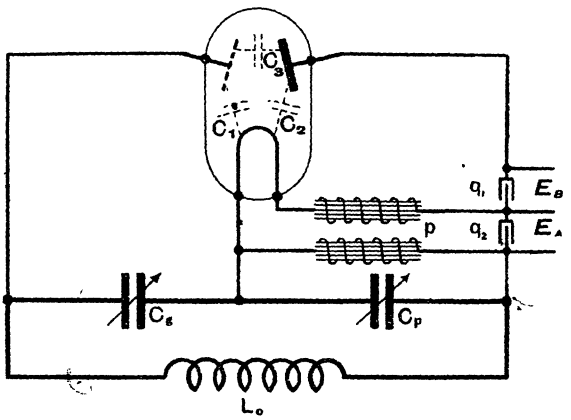

FIG. 4.—Modified Colpitt Circuit for High Frequencies.

The modification shown in Fig. 4 eliminates the choke between grid and filament. The choke p consists of double turns through which the filament current may be led. This simplification was found sufficient to reduce the wavelength to 10 metres.

CIRCUIT FOR PRODUCING VERY HIGH FREQUENCIES.

In order to produce wavelengths shorter than 10 metres it is necessary to substitute for the circuit having "lumped" inductance one having its inductance and capacity uniformly distributed.

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It has been found that by this arrangement wavelengths considerably less than two metres may be obtained with the VT–2 tube. The circuit diagram is shown in Fig. 5. The author has departed somewhat from the conventional methods of drawing such diagrams, in order to show the relative location of the apparatus in the circuit. The oscillatory circuit is indicated by the heavy lines. Its frequency is determined by the dimensions of the rectangle, the capacity C and the capacity between the electrodes of the tube.

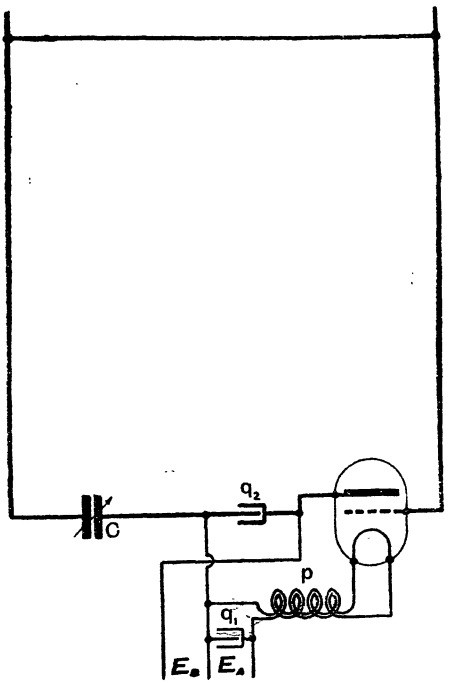

FIG. 5.—Circuit with Distributed Capacity and Inductance for generating Ultra-radio Frequencies.

The relative location of the apparatus in the circuit is of very great importance. The conductors through which the input is led, place three points of the circuit at earth potential. It is preferable therefore to locate these three points as close together as possible. Since the length of the rectangle is appreciable compared with the wavelength, waves are propagated along the rectangle and reflected at the ends. The ground imposed by the power leads may well be placed near the middle of the end of the rectangle. If the capacity of C is approximately equal to that of the tube, the voltage distribution along the two sides of the rectangle will be symmetrical. The wave front is therefore approximately perpendicular to the conductors forming the sides of the rectangle. This symmetrical condition may be

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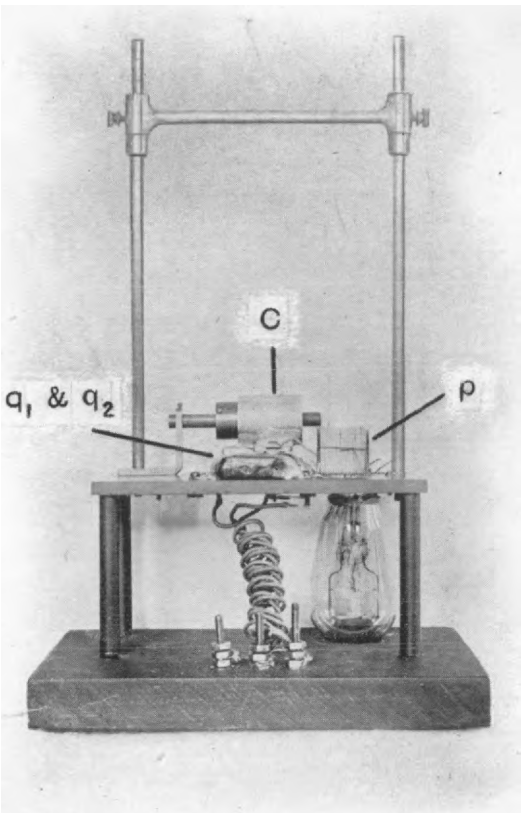

FIG. 6.

(*To face p.* 580.)

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verified by grounding corresponding points on the opposite sides of the rectangle and observing the power output. A second point at earth potential will be observed near the middle of the closed end.

A generator which was found to oscillate well at the highest frequencies mentioned above is shown in Fig. 6. The rectangle which is 13 cm. in width is variable from 8 cm. to 21 cm. in length. The condenser C consists of two concentric cylinders 3·2 cm. long with diameters of 1·8 cm. and 2·5 cm. The choke p is made by winding 11 double turns of No. 24 magnet wire on a former 2·2 cm. square and 2·2 cm. long. The stopping condensers q_1 and q_2 are made up of alternate sheets of foil and mica each 2·5 cm. square. Enough are assembled to make a capacity of about 1500 $\mu\mu$F. The electron tube is the U.S. Army Type VT–12. The capacities between the electrodes are about 5 $\mu\mu$F. each after the base has been removed. Other circuits used for developing high frequencies are described in the articles mentioned below.*

WAVELENGTH CALIBRATION OF THE GENERATOR.

The most accurate way of determining the wavelength of the generator is to couple it to a parallel wire system and measure the length of the standing waves produced. The details of this method will be given later.

The curves of Fig. 7 are the values of the wavelength of the generator plotted against the length of the rectangle. The family of solid curves is the calibration when the type VT–2 tube is used, the dotted line curves are obtained when the VT–12 tube is used, and the broken line curves are obtained with the VT–14.† Each curve is a result of a different setting of the condenser C. The removal of the unused portions of the conductors increases the stability of the circuit and makes it possible to obtain wavelengths shorter than those indicated in Fig. 7. A minimum wavelength of 110 cms. has been obtained with the VT–14 tube. From the straight line characteristic of these curves it is obvious that the wavelength is approximately proportional to the length of the rectangle. This verifies statements previously made, concerning the distributed nature of the capacity and inductance.

One might expect that the oscillatory circuit having distributed constants would reinforce certain harmonics. A careful investigation involving two different methods failed to detect either even or odd harmonics. One of the methods used would have detected any harmonic, the amplitude of which was one-half of one per cent. of the fundamental. This would indicate that the wave produced was approximately sinusoidal.

The power input of the generator shown in Fig. 6 as measured by the

* W. C. White, "The Pliotron Oscillator for Extreme Frequencies" (*General Electric Review*, 19, pp. 771—775, September, 1919). B. van der Pol, "The Production and Measurement of Short Continuous Electromagnetic Waves" (*Philosophical Magazine*, 38, pp. 90—97, July, 1919). C. Gutton and M. Touly, "Undamped Electric Oscillations of Short Wavelength" (*Comptes Rendus*, 168, pp. 271—274, February 3rd, 1919). Also *Revue Générale de l'Électricité*, March 15th, 1919.

† The VT-2, VT-12, and the VT-14 are types of power tubes used by the U.S. Army.

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product of the plate current and plate voltage varies with the adjustment of the circuit from 10 watts to 30 watts. In the latter case of course the tube is greatly overloaded. Inasmuch as 15 watts may easily be dissipated without excessive heating of the plates, we may conclude that the tube is being operated under fairly favourable conditions.

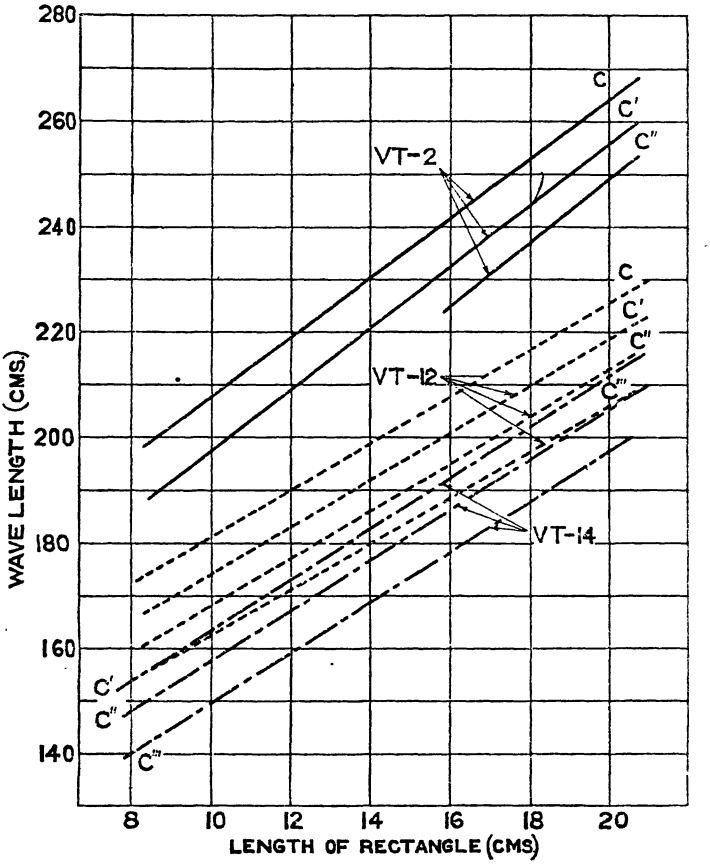

FIG. 7.—Calibration Curves for Electron Tube Generator of Ultra-radio Frequencies.

No satisfactory method is available for measuring currents at these high frequencies. In an early experimental circuit a shunted ammeter located in the oscillatory circuit indicated currents of 4 amperes. The nature of its shunt and the proximity of the meter case to other pieces of apparatus would indicate that the actual current was much greater than that read by the ammeter. It was also found that upon removing the meter the input was considerably reduced. This proved that the ammeter contributed an appreciable portion to the total losses.

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The constancy of this generator is approximately the same as for the tube circuits used for lower frequencies providing it is properly shielded. It was found that the output was seriously affected by reflecting objects located in the plane of the rectangle. This was particularly noticeable when the generator was coupled to a parallel wire system. In this case the current in the parallel wire system would fluctuate several per cent. as a person approached the generator in a direction along the plane of the rectangle. This apparently caused conditions of interference by reflecting back a portion of the radiated energy. This effect was noticeable at distances equal to several wavelengths.

METHOD OF MEASURING WAVELENGTH.

The resonator on which the standing waves are produced and measured consists of two parallel wires 5 cm. apart, which terminate in plane reflectors. One of these reflectors is made in two parts connected by a cross wire thermocouple. The other terminals of the thermocouple lead to a sensitive galvanometer of low resistance. The extra lengths of wire necessary for making adjustments pass through a conducting plane over pulleys and support weights which keep the parallel wires taut. Springs make positive contact between the wires and the thermocouple. The shielding effect of the conducting plane prevents standing waves on the extra lengths of wires or the galvanometer leads. The thermocouple and two-piece reflector are insulated from the shield by means of thin mica. The end of the resonator to which the generator is coupled is supported by a post mounted on a sliding platform.

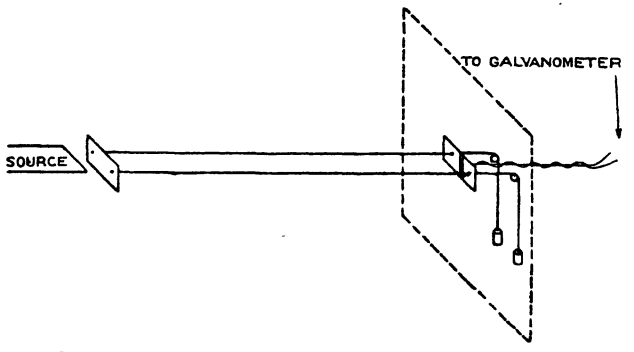

FIG. 8.—Arrangement of Apparatus for measuring Wavelength.

The generator being mounted on this platform enables the coupling to be kept constant while the conductors are being adjusted for length. A screw attached to the sliding platform permits an accurate adjustment of the lengths of the wires. The lengths are determined by a vernier attached to the platform which passes over a fixed scale. The arrangement of the generator and resonator is shown in Fig. 8.

A resonance curve plotted from corresponding readings of length of

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resonator and galvanometer deflections is shown in Fig. 9. The sharpness of resonance as defined by the ratio of the fractional change in the current to the fractional change in the length of the conductors is approximately 260. The sharpness of resonance for many wavemeter circuits used in radio is 40. The sharpness of resonance could be increased considerably by choosing a thermocouple of lower resistance.

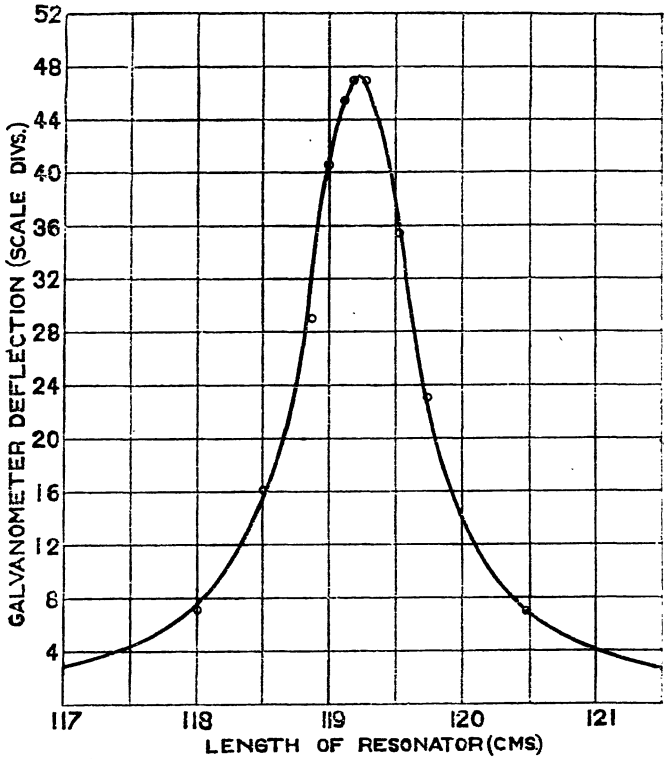

FIG. 9.—Resonance Curve.

The constancy of this type of generator and the degree of precision with which points of resonance may be determined make it especially adaptable to measurement purposes. Many of the corrections necessary when a damped source is used are eliminated. The applications of the electron tube to measurements at ultra-radio frequencies will be presented in a subsequent paper.

Yale University,
New Haven, Conn.
February 12th, 1920.

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Everyday Measurement of Inductance and Capacity in the Wireless Laboratory.*

By L. B. TURNER, M.A., M.I.E.E.

"The most important step in the progress of every science is the measurement of quantities," said Clerk Maxwell; and this is almost as true in the work of designing wireless apparatus as in that wider field of scientific research into the unknown to which the quotation strictly refers. Every competent wireless experimentalist either possesses or feels the want of means to measure quickly and easily those two most important dimensions of his equipment, the inductance and capacity of his coils and condensers. The more pressing need is for ease and rapidity, rather than for great precision, of measurement; and while a cupboardful of calibrated and labelled inductance coils of various shapes and sizes is a valuable possession, facilities for measuring in a moment the inductance of any half-stripped winding he may be handling is of much greater worth.

Since a wavemeter is a necessity in all wireless experimental work, it frequently happens that laboratory measurements of inductance and capacity, when made, are made by a method of wavemeter resonance. With the modern triode substitute for the buzzer generator of oscillation, this method is capable of giving precise results; but it is often both inconvenient and inaccurate; inconvenient in that to cover the wide ranges of values involved, many interchangeable standard coils and condensers must be used; inaccurate because all such high-frequency measurements are subject to great errors arising from stray inductances and capacities (especially the latter) unless troublesome precautions are taken and corrections applied. On the other hand, by resorting to measurement at low frequency, the self-capacities of coils, and the inductances and capacities of connecting wires and fittings, become negligible; so that if apparatus sufficiently simple and easily adjusted can be devised a low-frequency method is much more convenient than the wavemeter method. Urged by an experience of the need and the difficulties referred to, the writer was moved to design the two instruments described below.† When installed (immovably) in his laboratory, they quickly came to be regarded as almost indispensable instruments, partly as mere time savers, but even more as conferring that freedom and confidence which can rest only on a knowledge of the dimensions of the circuits handled.

INDUCTANCE BRIDGE.

For measuring inductances, the bridge circuit ‡ shown in Fig. 1 was adopted; the supply across one diagonal of the bridge being an interrupted

* Received June 21st, 1920.

† They were designed and constructed at the Signals Experimental Establishment, Woolwich, and the writer is indebted to Lieut.-Colonel Cusins, C.M.G., R.E., for permission to reproduce the photographs.

‡ Due to D. Owen, *Electrician*, July 30th, 1915.

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unidirectional current, and the detector across the other diagonal being an ordinary headgear telephone receiver. The conditions for balance are easily shown to be

$$(r_2 + r).C_2 = r_1.C_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\text{and} \qquad L = r_1.C_1.R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

These equations involve no frequency factor, so that the complications of a steady sinoidal generator of known frequency are avoided, and the much simpler device of a D.C. supply with buzzer interrupter is applicable.

In the bridge as constructed, r_1 and r_2 are made fixed resistances, and condition (1) is provided for by making C_2 a variable condenser. C_2 is referred to as the compensating condenser, being reduced in capacity to compensate for the resistance r of the inductance coil under test. The value of the inductance sought is given by condition (2), and is read off as the value of the external resistance R multiplied by the factor r_1C_1. It is convenient to read R in ohms and to evaluate L in microhenries. We have then

$$L \text{ (microhenries)} = R \text{ (ohms)} \times M$$

where the multiplier M is the product of r_1 in ohms and C_1 in microfarads

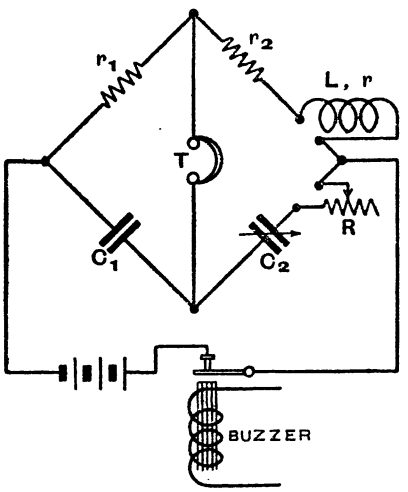

FIG. 1.—CONNECTION SCHEME OF INDUCTANCE BRIDGE.

For Balance: $(r_2 + r)C_2 = r_1C_1$ and $L = r_1C_1R$.

C_1 is made 0·0100 microfarad; r_1 (and r_2) can be plugged to any of the four values 1, 10, 100 or 1,000 ohms; so that M is made 0·01, 0·1, 1 or 10 at will. A photograph of the instrument, with lid removed, is shown in Fig. 2, the dimensions (with lid) being $10\frac{3}{4}$ ins. × $6\frac{1}{4}$ ins. × $5\frac{1}{2}$ ins. Fig. 3 gives the diagram of connections and instructions for use. The compensating condenser C_2 is uncalibrated; it is variable in mica steps by means of the six-stud switch, and continuously by an ebonite-air adjustable condenser connected in parallel.

With an external resistance box for R, preferably of decade dial pattern adjustable between 10 and 10,000 ohms in steps of 10 ohms, any inductance between one-tenth of a microhenry and one-tenth of a henry can be measured in a couple of minutes or so. All the resistances should, of course, be sensibly non-reactive at the frequency employed. The internal resistances r_1 and r_2 are constructed of fine Eureka wire (S.W.G. 44) wound on thin ebonite plates; and it is possible to purchase (for R) the non-reactive resistance boxes used for telephonic measurements. But Table I. shows that the more ordinary bifilar bobbin resistances are good enough.

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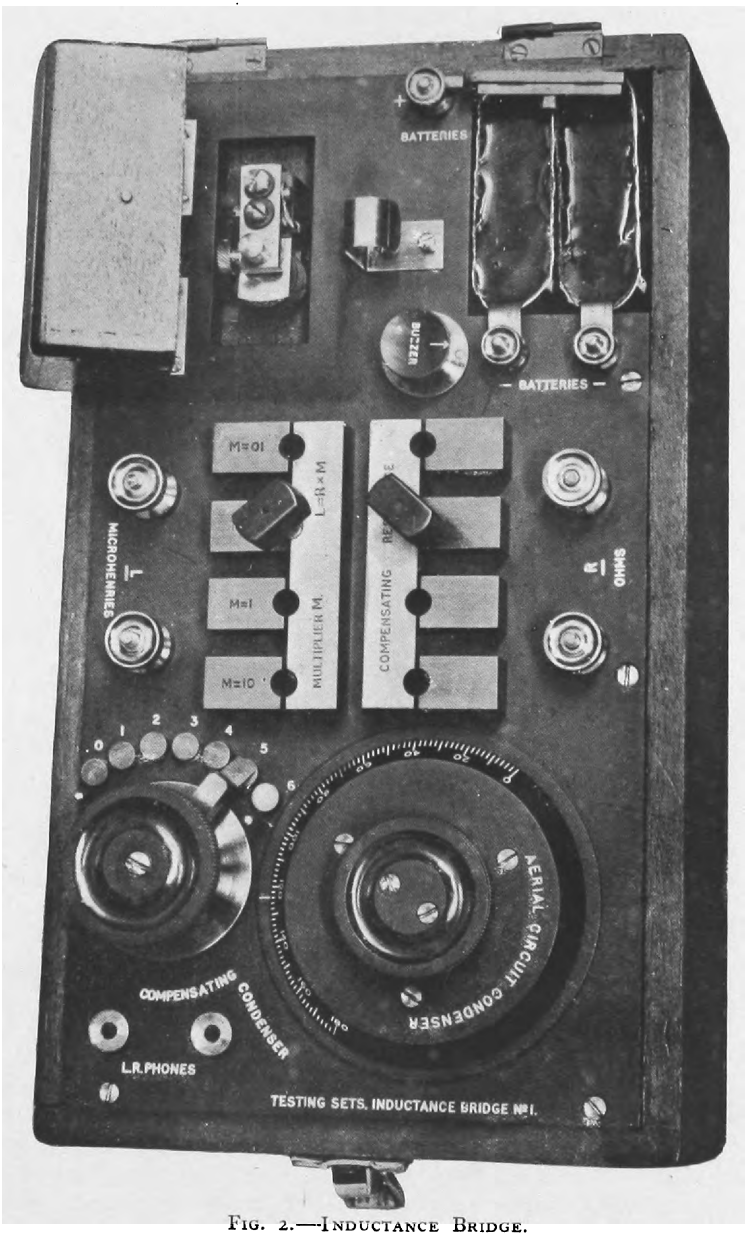

FIG. 2.—INDUCTANCE BRIDGE.

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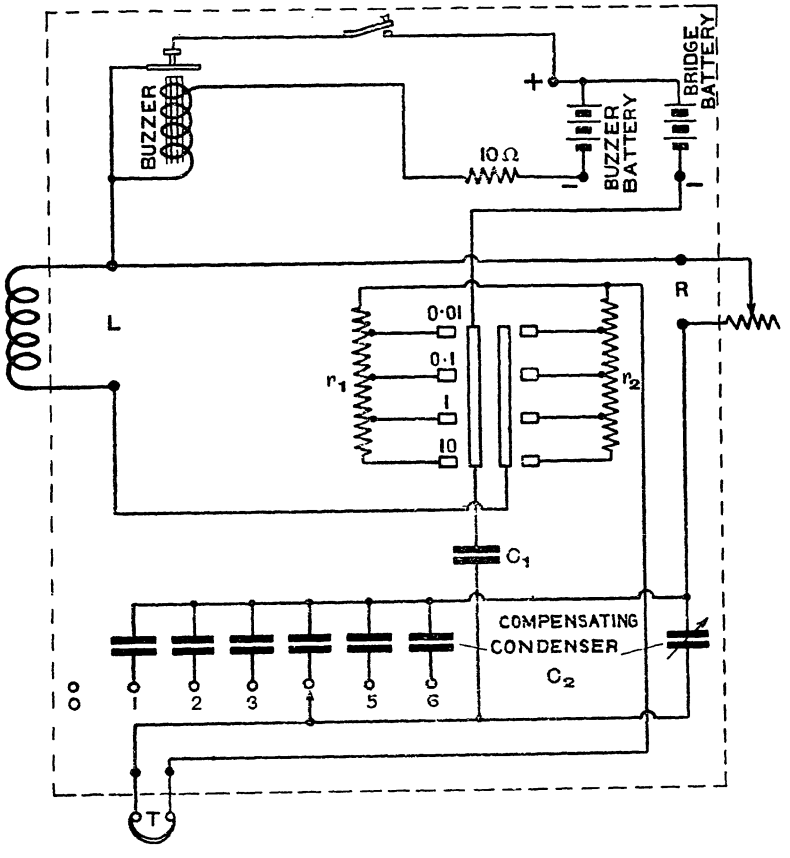

$C_1 = 0{\cdot}0100\ \mu F$. $C_2 = C_1$ or less according to value of r. r_1 and r_2 are each 1, 10, 100, or 1,000 Ω according to position of plugs.

INSTRUCTIONS.

(1) Join unknown inductance to terminals L and resistance box to terminals R.
(2) Set both plugs to M = 0·01, 0·1, 1 or 10 according as L is below 100, 1,000, 10,000, or 100,000 microhenries respectively.
(3) Obtain silence in phones by adjusting C_2 (roughly, by switch); then R; then C_2 (finely, by rotary condenser). When C_2 and R are *both* finally adjusted, silence should be almost perfect. Then

$$L \text{ (microhenries)} = M \times R \text{ (ohms)}.$$

(4) Beware of inductance of leads to terminals L; and of induction between coil under test and phones, especially when M = 0·01.
(5) Exceptionally, when r is very large, it is convenient to plug r_2 to a value less than r_1.

FIG. 3.—INDUCTANCE BRIDGE.

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TABLE I.

Inductances measured by the bridge, using for R:—
(*a*) Paul non-reactive decade resistance box;
(*b*) "Megger" decade resistance box.

Microhenries.	
By (*a*).	By (*b*).
3·7	3·9
17·6	17·7
554	554
5,150	5,140
47,500	47,400

Simple, *i.e.*, not bifilar, bobbin resistances of 10, 100 and 1,000 ohms were also found to be satisfactory. A cheap resistance box (for R) made up with such bobbins is shown in Fig. 4. In a subsequent improvement a twelfth stud was added to each dial—a great convenience in balancing at values of R with which otherwise a change of $\pm$ one stud would not be possible on each dial (*e.g.*, on the hundreds dial if $R = 8050$).

The first bridge set up having been constructed with independently measured * capacity and resistances, two coils were measured on the bridge and at the National Physical Laboratory. The values obtained are shown in Table II.

TABLE II.

Microhenries.	
N.P.L.	Bridge.
82·8	83·2
1,064	1,051

CAPACITY BRIDGE.

The method adopted for measuring capacities was that of a simple Wien bridge comparison between the unknown capacity and a variable known capacity, with resistance ratio arms, buzzer for generator, and telephone for detector, as in Fig. 5. Except when there is a leakage defect, wireless condensers present sensibly pure capacity in such a bridge. There is therefore a single condition for balance, and the frequency is not involved; viz.

$$C/C' = R/R'$$

In order to measure unknown capacities which are smaller than the minimum capacity of the calibrated condenser C', and at the same time to correct for stray capacities which are perceptible when the unknown condenser is small (*e.g.*, a few micromicrofarads), the capacity C is made up of the unknown condenser (when connected) plus an uncalibrated fixed mica condenser and small adjustable air condenser in parallel within the instrument.

* At the Signals Experimental Establishment, without any refinements.

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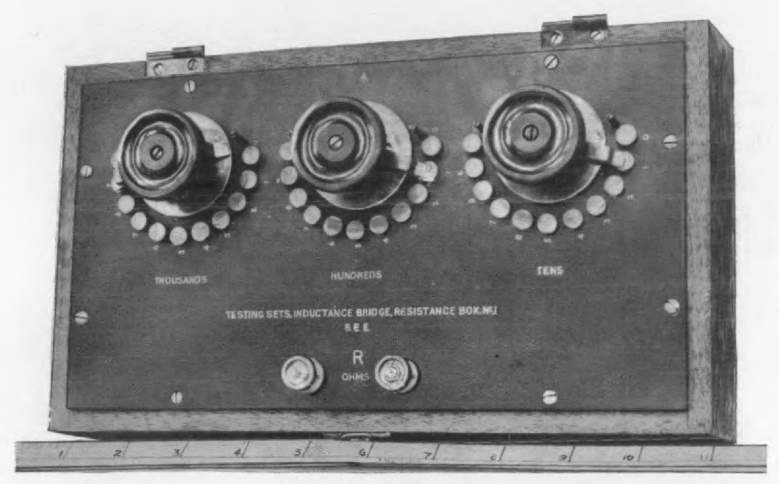

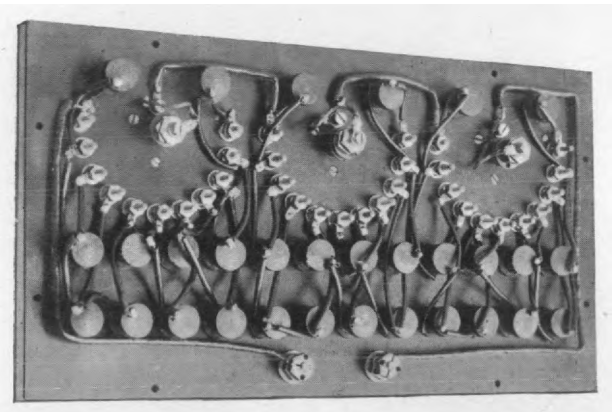

FIG. 4.—RESISTANCE BOX.

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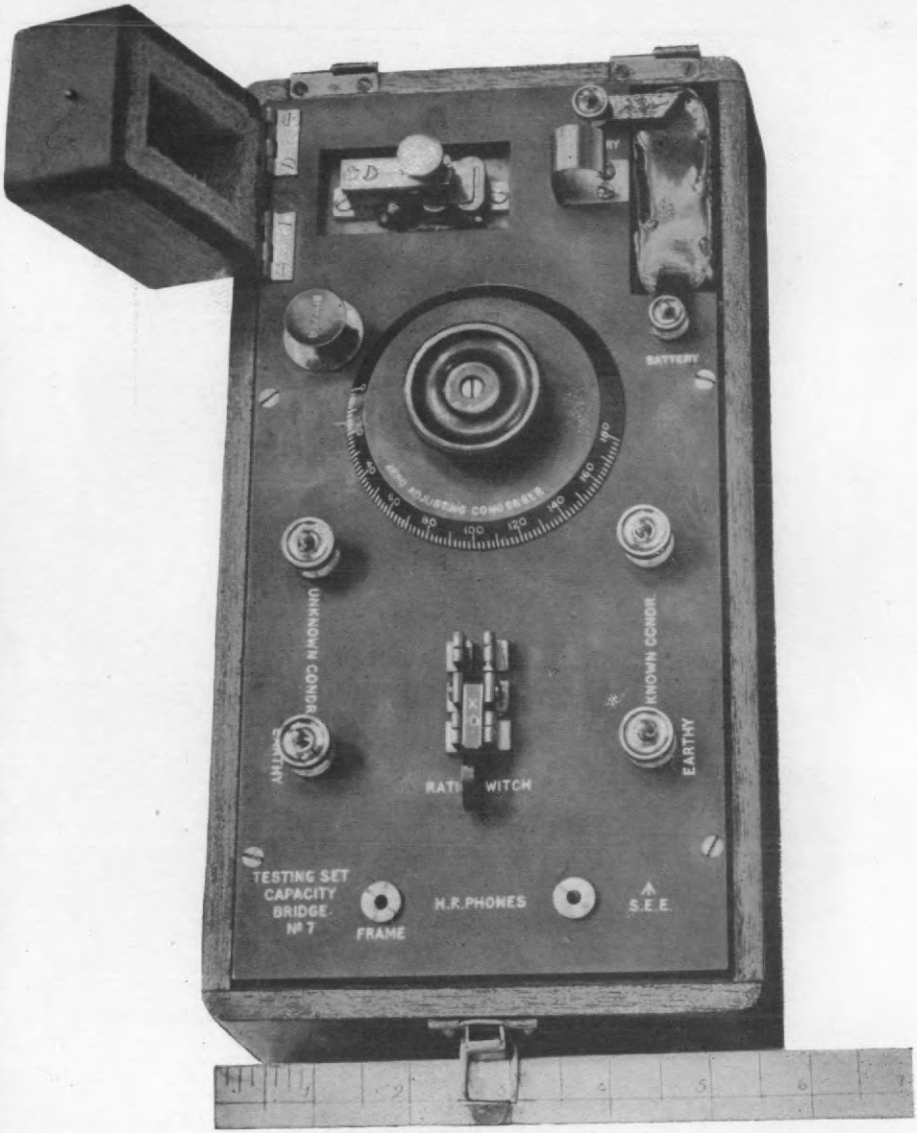

FIG. 6.—CAPACITY BRIDGE.

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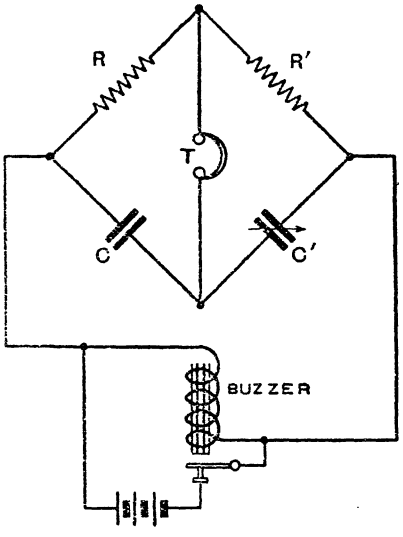

FIG. 5.—CONNECTION SCHEME OF CAPACITY BRIDGE.

The bridge is balanced before and after finally connecting the unknown condenser, which is thus measured by the difference $(C_2 - C_1)$ between the two readings of C'. The small internal adjustable air condenser, referred to as the zero adjusting condenser, is provided to save mental effort by making C_1 assume a value (such as 100 micromicrofarads) convenient for subtraction from C_2.

A photograph of the bridge, exclusive of the external calibrated condenser C', is reproduced in Fig. 6. The overall dimensions are approximately the same as those of the inductance bridge (Fig. 2). Fig. 7 shows the actual connections and values adopted in the instrument, together with the instructions for use. It will be seen that two resistance ratios are provided, 1 : 1 and 10 : 1.

The external adjustable calibrated condenser C' may be of any pattern and size. The bridge was primarily designed for use with an air condenser of high quality (by H. W. Sullivan) with scale calibrated in micromicrofarads between about 70 and 1,200. Capacities between 2 and 11,000 micromicrofarads are then measurable with great ease and rapidity. A testimonial at once to the precision with which the balance can be observed, and to the constancy of good mica-wax condensers and of the Sullivan adjustable air condenser, is provided by Table III. Measurements of three mica-wax condensers were made with the bridge independently on different occasions separated by considerable intervals of time, and gave the fairly close results shown in the Table.

TABLE III.

Micromicrofarads.		Months of interval.
First measurement.	Second measurement.	
5,250	5,270	1
415	413	10
409	409	10

It may be suggested that the measurement at low frequency of condensers destined for high frequencies might lead to error or confusion. But it must be remembered that air capacities do not depend on frequency at all, and that mica capacities vary only very slightly indeed over the range of frequencies we are concerned with. H. L. Curtis * found for mica that changing

* *Electrical Review and Western Electrician*, 1911.

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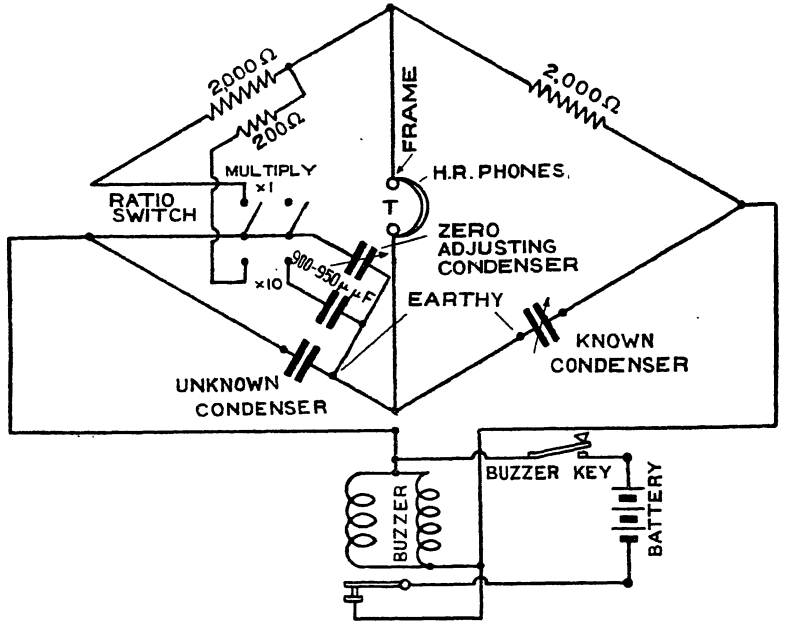

INSTRUCTIONS FOR USE.

(1) Set ratio switch to a multiplier suitable for capacity to be measured.
(2) Connect the earthy or case terminal of unknown condenser, leaving the other dis.
(3) Set the known condenser to any convenient capacity C_1 (such as 100 micromicrofarads) and balance for silence in phones by means of the zero adjusting condenser.
(4) Connect other terminal of unknown condenser (without much disarrangement of leads) and rebalance by moving known condenser to capacity C_2.
(5) The capacity of unknown condenser is then $(C_2 - C_1)$ or $10(C_2 - C_1)$, according to ratio switch.

N.B.—Always observe the distinction between the earthy (case or frame) terminal and the other terminal of unknown and known condensers.

FIG. 7.—CAPACITY BRIDGE.

the frequency from 12 to 1,200 periods per second altered the capacity by only some 0·07 per cent.; and the present writer's measurements with a mica-wax condenser show that a change from buzzer frequency to 6×10^6 periods per second was accompanied by a change in capacity of certainly less than 1 per cent. It may be added that Curtis also found that changing the P.D. of a mica condenser between nearly zero and 50 volts altered the capacity by only about 0·1 per cent.

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The Diffraction of the Field by a Cylinder and its Effect on Directive Reception on Board a Ship.

By Commandant RENÉ MESNY.

(*Continued from page* 540.)

II.—APPLICATION TO SHIPS.

9. General Formula for the Deviation of the Radiogoniometric Bearings taken on a Ship.—Let us now examine the deviation to which an observation made with a radiogoniometer on board a ship is subjected. Since the frame aerials used are of small dimensions, we may assume that the field is uniform over their area, and so we need only examine the field at their centre.

It has been shown elsewhere that a field in quadrature with the main field can be compensated, and will not produce any appreciable deviation if the ratio between the field in quadrature and the main field is less than one-twentieth.

Hence we can examine the deviation by combining the wave field H' with the inphase disturbing field Y_1, and by calculating the angle δ between H' and their resultant. Fig. 5 shows the fields H' and Y_1 in the plane yz, taking account of the conventions of sign defined above, the x axis being parallel to the axis of the ship.

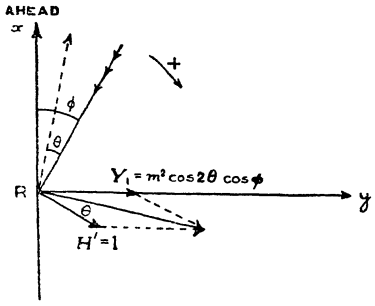

FIG. 5.

Hence for the deviation of the field H' from the resultant, *i.e.*, if δ = (observed azimuth — true azimuth), we find by projecting H' and Y_1 on the normal to their resultant

$$\sin\delta + m^2 \cos 2\theta \,.\, \cos\phi \,.\, \sin(\phi - \delta) = 0$$

whence
$$\tan\delta = -\frac{m^2 \cos 2\theta}{2} \times \frac{\sin 2\phi}{1 + m^2 \cos 2\theta \cos^2\phi} \quad . \quad . \quad . \quad . \quad (16)$$

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10. Radiogoniometer on the Ship's Axis.—If the apparatus is on the ship's axis $\theta = 0$, and we may write the preceding equation in the form

$$\tan\delta = -\frac{m^2}{(2+m^2)+m^2\cos 2\phi}\cdot\sin 2\phi \quad . \quad . \quad . \quad . \quad (17)$$

By examination of this formula we are led to the following conclusions :—

(*a*) The deviation is independent of the wavelength.

(*b*) It takes a quadrantal form, with maxima at bearings of 45°, 135°, 225°, and 315°.

(*c*) The observed bearing is always nearer the axis than the true bearing.

(*d*) The slope of the curve is greater athwartships than in a fore-and-aft direction.

11. Tests.—The above paragraphs (*a*), (*b*) and (*c*) agree well with observations ; it is known that the deviation is only dependent on the wavelength when it is less than three times the length of the ship—in which case the theoretical results are evidently no longer applicable.

With a view to verifying equation (17) quantitatively Table I. below has been prepared, giving the following particulars, all lengths being in metres.

L = maximum length of the vessel.

l = maximum width of the vessel.

c = maximum depth of the vessel.

l' = width of vessel at the point where the radiogoniometer is fitted.

c' = depth of vessel at the point where the radiogoniometer is fitted.

h = height of the centre of the radiogoniometer above the upper deck.

d = distance of the radiogoniometer from the stern.

ρ_m = mean radius of the section of the ship at the place where the radiogoniometer is fitted.

Δ = the maximum observed deviation.

Δ' = the maximum deviation calculated from ρ_m and h.

ρ_0 = the radius of the imaginary cylinder which would produce the same deviation as the ship, calculated from equation (17) by means of m and Δ.

TABLE I.

Name of Vessel.	L	l	c	l'	c'	h	ρ_m	Δ'	Δ	ρ_0	d
Leonce Raynaud	35	6·0	3·0	6·0	3·0	2·10	**2·25**	**7·5°**	**7·5°**	**2·25**	21
Ditto . .	35	6·0	3·0	6·0	3·5	3·60	**2·40**	**4·5°**	**4·0°**	**2·15**	4·5
Dunois . .	78	8·5	6·8	8·5	6·8	5·75	**3·80**	**4·5°**	**5·0°**	**4·15**	30
Ditto . .	78	8·5	6·8	5·1	3·4	3·50	2·10	4·0°	7·0°	3·50	—
Gloire . .	140	20·2	13·5	10·0	13·5	3·50	**5·90**	**10·7°**	**11·0°**	**6·10**	11
Paris . .	165	27·0	16·0	14·5	14·0	3 50	7·10	12·0°	9·0°	4·60	19
Ditto . .	165	27·0	16·0	25·0	16·0	10 00	10·20	6·0°	8·0°	14·00	55

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The agreement between Δ and Δ' on the one hand, and between ρ_m and ρ_0 on the other is as close as could be expected in the cases of the figures printed in heavy type. For the others the differences are rather large, but they nevertheless suffice to establish the principles upon which the formula is based. It may be noted also that the discordant results in the case of the *Dunois* and the first deviation readings of the *Paris* occur with the radiogoniometer very close to the stern, and that in the case of the second reading of the *Paris* the radiogoniometer was on a cabin of rather large size, of which no account has been taken. Further, in these three cases the apparatus was only 3—4 metres away from large metallic bodies (superstructure, masts, turrets).

Finally paragraph (*b*) is again verified by the deviations of the *Leonce Raynaud*. These deviations are set out by the points marked in Fig. 6.

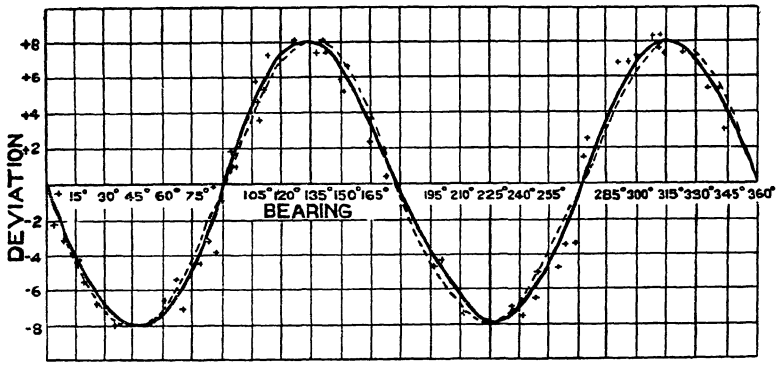

FIG. 6.—DEVIATION CURVES OF THE "LEONCE RAYNAUD."

Full line curve:—$\tan\delta = -\dfrac{m^2 \sin 2\phi}{2 + m^2 + m^2 \cos 2\phi}$.

Dotted curve:—$\tan\delta = 7{\cdot}5° \sin 2\phi$.

The full curve on this diagram is the curve given by equation (17) and the dotted curve that given by $\tan\delta = -\Delta \sin 2\phi$. It is seen that the former agrees better with the observations as a whole than does the latter.

12. Variation of the Deviation with the Height of the Radiogoniometer.—The maximum deviation is given by the formula:

$$\tan\Delta = \frac{m^2}{2 + m^2} = \frac{{\rho_0}^2}{2\rho^2 + {\rho_0}^2}$$

or if h is the height of the centre of the frame above the deck

$$\tan\Delta = \frac{{\rho_0}^2}{3{\rho_0}^2 + 4\rho_0 h + 2h^2}$$

From this it is evident that the maximum deviation which is obtained when $h = 0$ is

$$\Delta_{max} = 18{\cdot}5°$$

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Of course this maximum value is only valid for waves considerably longer than the vessel (approximately three times).

Table II. gives the approximate deviations that may be expected as functions of the height h of the centre of the frame above the deck and of the mean radius ρ_m of the hull of the vessel at the point where the radiogoniometer is fitted—the radius ρ_m being taken as one-fourth of the sum of the width and depth of the vessel.

TABLE II.

ρ_m Metres.	Heights h in metres.						
	1	2	3	5	10	20	30
2·5	11·5°	7·6°	5·4°	3·0°	1·1°	—	—
4·0	13·6°	10·3°	8°	5·1°	2·2°	—	—
6·0	15·0°	12·4°	10·3°	7·3°	3·7°	1·5°	—
10·0	16·3°	14·5°	12·8°	10·3°	6·3°	3·0°	1·7°

13. Radiogoniometer in other Positions.—For these cases we must apply equation (16) which only differs from the one corresponding to the case with the apparatus on the axis in that the term m^2 is multiplied by $\cos 2\theta$. Therefore if we assume that the bulwarks do not introduce any disturbances in the phenomenon studied, there should only be a diminution of the deviation.

On the other hand the quadrature field X_2Y_2 (see section 7) which disappears on the axis will no longer be zero, and the compensation will be modified. It has been shown elsewhere that the component of the quadrature field which gives rise to the compensation is the one normal to the principal field. Therefore neglecting Y_2 (which is small compared with X_2), it is obviously given by

$$X_2 \cos \phi = \frac{\pi \rho_0}{\lambda} \left(\frac{\rho_0}{\rho}\right) \sin \theta \,.\, \sin^2 \phi \,.\, \cos \phi.$$

The curve of this function is again of the quadrantal form, but it is much flatter for $\phi = 0°$ or $180°$ than for $\phi = 90°$ or $270°$. For the two former values of ϕ it is even tangent to the axis of the bearings of the transmitter.

No results are available of observations taken on such installations, but the curves in Fig. 9, which will be dealt with in section **15**, provide a confirmation of the preceding facts.

14. The Effective Height of a Ship Antenna.—In section **8** it was shown that the vertical electric field of the ship was equal to $(\rho_0/\rho)^2$

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when the wave field was 1. It therefore adds to this latter and gives the same resultant as would an increase of the effective height. Thus the hull participates with the aerial in the work of reception whatever the direction of the incoming wave. Let us examine the magnitude of this effect.

Let A B, Fig. 7, represent the downleads of an antenna, of which we may suppose the whole of the capacity to be concentrated in a horizontal part situated at B. Its effective height, taking account of the wave field only, will be equal to A B, but to this field, assumed equal to unity, must be

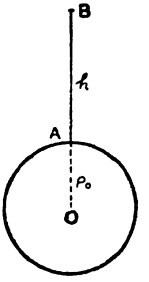

FIG. 7.

added at each point, the field due to the ship, which equals $(\rho_0/\rho)^2$. This is the same as if we added its mean value throughout the whole height of the antenna. This mean value, putting A B $= h$, is

$$\frac{1}{h}\int_{\rho_0}^{\rho_0+h}\left(\frac{\rho_0}{\rho}\right)^2 d\rho = \frac{\rho_0}{\rho_0+h}$$

The mean field acting on the aerial is therefore

$$1+\frac{\rho_0}{\rho_0+h}$$

or in another form, the effective height of the antenna is multiplied by the factor $\left(1+\frac{\rho_0}{\rho_0+h}\right)$.

This increase is far from being negligible particularly for torpedo boats or submarines with very low aerials.

We may therefore state the following proposition :—

To obtain the effective height of a ship's aerial for reception, the height h above the upper deck calculated by the usual methods, must be multiplied by the factor

$$1+\frac{\rho_0}{\rho_0+h}$$

where ρ_0 is one-fourth of the sum of the width and the depth of the vessel.

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III.—APPLICATIONS TO DIRECTION FINDERS ON HILLS.

15. Analogies with the "Cylinder" Problem.—Some results obtained with Direction Finding stations installed on hills have already been published. The most interesting are those relative to the Ile des Sanguinaires in Corsica. The map of this island which lies in a N.E.—S.W. direction is given in Fig. 8. It has an almost rectilinear summit at an altitude varying slightly around 75 metres.

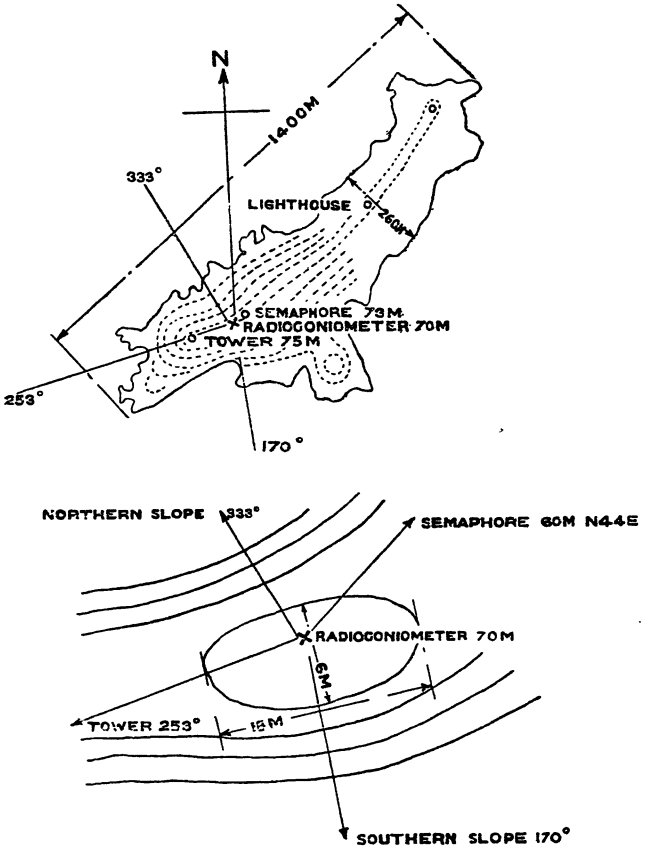

FIG. 8.—MAP OF THE ILE DES SANGUINAIRES (CORSICA).
The lower diagram shows the location of the radiogoniometer.

The comparison of this case with that of a semi-cylinder is obviously impossible, and the problem of this form of obstacle must be treated separately. Nevertheless it is felt that certain analogies exist between the two questions, and this feeling is fully confirmed by an examination of the curves in Fig. 9.

(*a*) The deviation is quadrantal.

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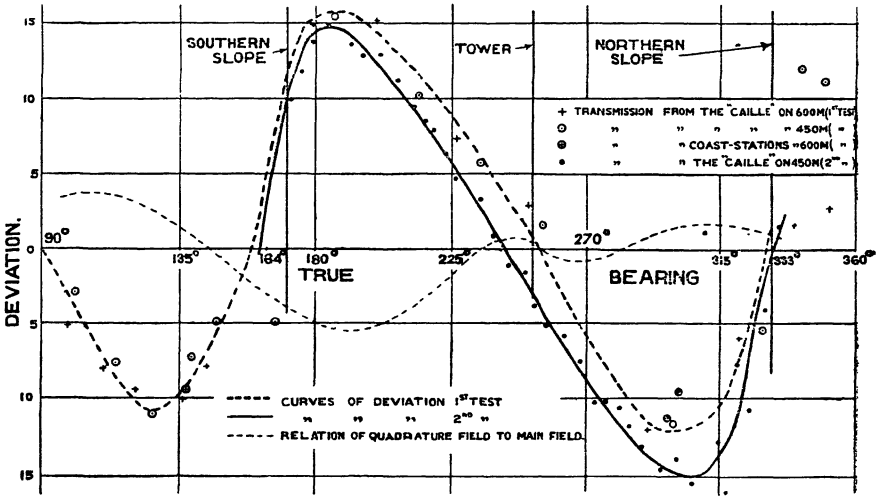

FIG. 9.—DEVIATION CURVES FOR THE ILE DES SANGUINAIRES.

(*b*) It is zero along the axis, and across the island.

(*c*) The slope of the curve is steeper at the zero corresponding to bearings across the island, than for those in the neighbourhood of the axis.

(*d*) And finally the curve of the disturbing field in quadrature with the main field confirms the prediction of section **13.** It is quadrantal and becomes tangential to the axis of the true bearings in the direction of the axis of island.

16. Variation of the Field in the Neighbourhood of the Summit.—The second sketch in Fig. 8 gives details of the mounting of the direction finder on the crest of the island. It is installed on a small elliptic plateau which had been prepared during the war for the mounting of a battery; it was not placed exactly at the centre of this small plateau, but as the latter was entirely on the crest, the radiogoniometer may be regarded as being very close to the vertical plane passing through the mean summit line.

If in the absence of a better analysis we seek to extend the conclusions of the preceding investigation to this actual case, we might suppose θ to be very small and the disturbing field in quadrature to be negligible. This is, however, far from being the case.

Among the hypotheses to which this statement might give rise the following seems the most plausible:

On the summit of a hill with steep sides, the field at a point varies rapidly as the point moves over relatively short distances (a few metres only). It will thus be possible in a restricted space to find sites possessing very different properties for the installation of the Direction Finding station.

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SPECIAL EDITORIAL NOTICE.

In view of the greater convenience for indexing and reference purposes of technical periodicals which have their volumes running concurrently with the year, it has been decided to extend the present volume of the "Radio Review" to December next. Volume II. will therefore commence with the January, 1921, issue. The publication of the classified index to the Abstracts in the current volume will therefore be held over to the early part of next year.

The Power required for Long Distance Transmission.

By THE EDITOR.

In referring to the wavelength at which a transmitting aerial is working it is customary to take as a basis of reference the wavelength corresponding to the fundamental frequency of the aerial, *i.e.*, with all tuning coils cut out. As we showed in our last issue, however, there is another characteristic wavelength, namely that at which the total effective resistance is a minimum. At this wavelength the dielectric losses are twice as great as the radiated power. In this article we propose to show the importance of this wavelength in all calculations of the efficiency of radio transmission.

Assuming the aerial to have a large upper capacity and to be radiating at a wavelength very large compared with the height, we have for the radiated power

$$P_{rad} = 1{\cdot}584 \frac{h^2}{\lambda^2} I^2 \text{ kilowatts}$$

where I is the root-mean-square current in amperes. The electric field strength at a distant point of the earth's surface is given by the formula

$$E = \frac{4\pi}{10} \cdot \frac{h}{\lambda} \cdot \frac{I}{d} \text{ e.s. units}$$

$$= 120\pi \frac{h}{\lambda} \cdot \frac{I}{d} \text{ volts per cm.}$$

where d is the distance in centimetres. This is the theoretical value on the assumption that the earth is a plane perfect conductor and that the atmosphere is a perfect dielectric of infinite extent.

Now the power supplied to any receiving station by the electromagnetic waves is proportional to E^2, and to be able to read the signals through atmospheric disturbances it is necessary that the value of E at the receiving station should exceed a certain value. This is not much affected by the size of aerial and degree of amplification employed since these factors influence the loudness of both signals and atmospheric noises. We are neglecting here any secondary differences due to directive effects, etc.

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Putting D for the distance in kilometres, we have

$$E^2 = \frac{14400 \cdot \pi^2}{10^{10}} \cdot \frac{h^2}{\lambda^2} \cdot \frac{I^2}{D^2} \qquad (E = \text{volts per cm.})$$

and therefore

$$\frac{P_{rad}}{E^2} = \frac{1{\cdot}584 \cdot 10^{10}}{14400 \cdot \pi^2} \cdot D^2 \left(\frac{\text{kilowatts}}{(\text{volts per cm.})^2}\right)$$
$$= 1{\cdot}11 \cdot 10^5 \cdot D^2$$

If P is the total power supplied to the transmitting aerial, the ratio of P_{rad} to P may be called the efficiency of the aerial and we may write

$$\frac{P_{rad}}{P} = \eta.$$

We shall assume here that the theoretical formula just established is brought into agreement with experimental results by the introduction of the Austin-Cohen exponential factor. The formula then becomes

$$\frac{P}{E^2} = 1{\cdot}11 \cdot 10^5 \cdot \frac{D^2}{\eta} \cdot \epsilon^{0{\cdot}003D/\sqrt{\lambda}}$$

where D and λ are both in kilometres.

L. W. Austin found that to give readable signals at Brant Rock when receiving from U.S. cruisers, it was necessary to have a received current of 40 microamperes set up in the antenna which had a total effective resistance of 25 ohms and an effective height of about 200 feet. To produce a current of $40 \cdot 10^{-6}$ amperes in 25 ohms requires an electromotive force of 0·001 volt, which divided by the effective height of the aerial gives a field strength of $1{\cdot}64 \cdot 10^{-7}$ volts per centimetre.

Inserting this value of E in the above formula we get

$$P = 3 \cdot 10^{-9} \cdot \frac{D^2}{\eta} \cdot \epsilon^{0{\cdot}003D/\sqrt{\lambda}} \text{ kilowatts.}$$

To ensure a reliable commercial service under all conditions a considerable factor of safety should be introduced. Assuming a factor of 5, the formula becomes

$$P = 15 \cdot 10^{-9} \cdot \frac{D^2}{\eta} \cdot \epsilon^{0{\cdot}003D/\sqrt{\lambda}} \text{ kilowatts.}$$

This gives an electric field strength E at the receiving station of 0·37 microvolt per cm.

We shall now consider more closely the value of the efficiency η of the transmitting aerial. Let β be the ratio of the conductor resistance R_w of the aerial-earth system, which we assume to be constant for all wavelengths, to the minimum value R_m of the total effective resistance; then

$$R_w = \beta R_m = \beta(R_w + R_{dm} + R_{rm})$$

where R_{dm} and R_{rm} are the dielectric and radiation resistances, respectively, at the wavelength λ_m for which the total effective resistance R_m is a minimum.

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Since, at this wavelength, $R_{dm} = 2R_{rm}$, we have

$$R_m = \beta R_m + 3R_{rm}$$

and

$$R_{rm} = R_m \cdot \frac{1-\beta}{3}.$$

Since the dielectric resistance is directly proportional to λ, whilst the radiation resistance is inversely proportional to λ^2, we have

$$R = \beta R_m + 2\gamma R_{rm} + \frac{R_{rm}}{\gamma^2}$$

$$= R_m\left\{\beta + \frac{1-\beta}{3}\left(2\gamma + \frac{1}{\gamma^2}\right)\right\}$$

where

$$\frac{\lambda}{\lambda_m} = \gamma.$$

Of this total resistance R, the only useful part is that representing the radiation, viz. :—

$$R_r = \frac{R_{rm}}{\gamma^2} = R_m \frac{1-\beta}{3\gamma^2}.$$

Hence

$$\frac{1}{\eta} = \frac{R}{R_r} = \frac{3\gamma^2\beta}{1-\beta} + 2\gamma^3 + 1$$

Table I. below gives the calculated values of $1/\eta$ for various values of β and γ. These values are plotted in Fig. 1 for $\beta = 0{\cdot}1$, $0{\cdot}3$, and $0{\cdot}5$.

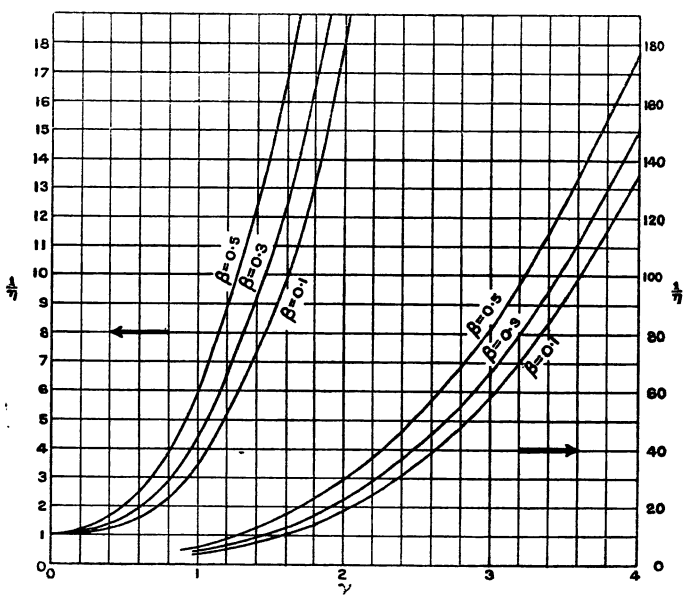

FIG. 1.

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TABLE I.

$$\frac{1}{\text{aerial efficiency}} = \frac{1}{\eta}.$$

$\beta = \frac{R^w}{R_m}$	$\gamma = \lambda/\lambda_m =$								
	0·5	0·75	1	1·5	2	2·5	3	4	5
0·1	1·33	2·03	3·33	8·5	18	34	58	134	259
0·2	1·44	2·26	3·75	9·4	20	37	62	141	270
0·3	1·57	2·56	4·3	10·6	22	40	67	150	283
0·4	1·75	2·96	5	12·2	25	45	73	161	301
0·5	2·0	3·53	6	14·5	29	51	82	177	326

TABLE II.

Power in kilowatts for D = 1,000 kilometres.

λ_m	β	$\gamma = 0·5$	$\gamma = 0·75$	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$
0·5	0·1	8·05	4·1	3 5	5·5	10·1	26
	0·5	12·10	7·1	6·3	8·7	14·25	32·75
1·0	0·1	1·4	1·0	1·0	2·3	4·9	14·85
	0·5	2·1	1·7	1·8	3·6	6·95	18·7
2·5	0·1	0·3	0·275	0·335	1·05	2·6	9·1
	0·5	0·45	0·475	0·6	1·65	3·7	11·4
5·0	0·1	0·135	0·145	0·2	0·7	1·9	7·05
	0·5	0·2	0·25	0·35	1·1	2·65	8·9
10·0	0·1	0·075	0·09	0·13	0·535	1·5	5·95
	0·5	0·115	0·16	0·235	0·845	2·125	7·5

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These figures are very striking; they show that if a warship with an aerial for which $\lambda_m = 1{,}000$ metres transmits at a wavelength of 3,000 metres, less than 2 per cent. of the energy actually supplied to the aerial is radiated, the remaining 98 per cent. being dissipated in aerial losses, whereas at a wavelength of 1,000 metres 30 per cent. may be radiated.

If the values of β and γ are known the corresponding value of η can be substituted in the formula established above for the power P which must be supplied to the transmitting aerial. It is seen that P depends only on β, γ, D, and λ_m. We have calculated P for five values of D, viz., 1,000, 2,000, 3,000, 5,000 and 10,000 kilometres, for two values of β, viz., 0·1 and 0·5, for six values of γ, viz., 0·5, 0·75, 1·0, 2·0, 3·0 and 5·0, and for five values of λ_m, viz., 0·5, 1·0, 2·5, 5·0 and 10·0 kilometres. The actual wavelength in any case is equal to $\gamma\lambda_m$.

The values of the power P in kilowatts are given in the Tables II. to VI., and in Figs. 2 to 6. The curves have only been plotted for one value of β, viz. $\beta = 0{\cdot}1$.

TABLE III.

Power in kilowatts for $D = 2{,}000$ kilometres.

λ_m	β	$\gamma = 0{\cdot}5$	$\gamma = 0{\cdot}75$	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$
0·5	0·1	13,000	2,200	980	445	475	695
	0·5	19,500	3,800	1,765	700	660	875
1·0	0·1	395	125	80	75	110	225
	0·5	590	215	145	120	155	285
2·5	0·1	17	10	9	16	31	84·5
	0·5	25·5	17	16	25·5	44	106·5
5·0	0·1	3·6	2·7	2·9	7·35	16·4	51·5
	0·5	5·35	4·2	5·25	11·65	23·15	65
10·0	0·1	1·15	1·1	1·35	4·2	10·4	36·25
	0·5	1·75	1·9	2·4	6·65	14·75	45·75

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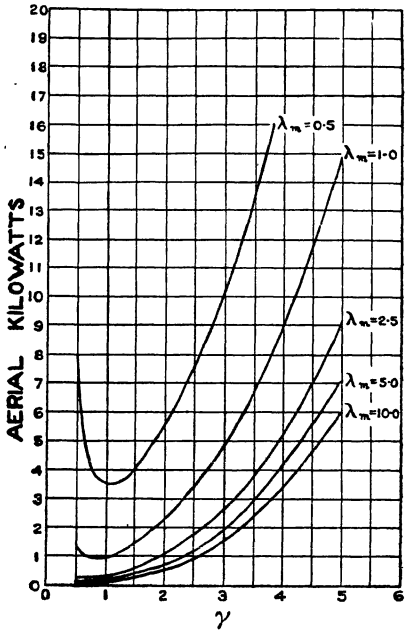

FIG. 2.

D = 1,000 kilometres; β = 0·1.

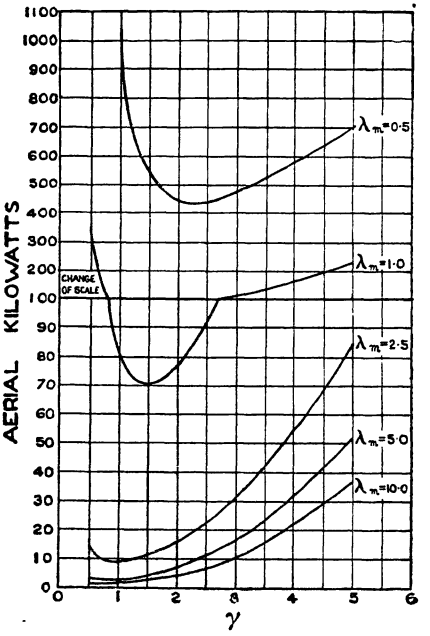

FIG. 3.

D = 2,000 kilometres; β = 0·1.

TABLE IV.

Power in kilowatts for D = 3,000 kilometres.

λ_m	β	$\gamma = 0{\cdot}5$	$\gamma = 0{\cdot}75$	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$
0·5	0·1	—	—	155,000	20,000	12,200	10,450
	0·5	—	—	280,000	31,750	17,200	13,150
1·0	0·1	62,000	8,825	3,650	1,430	1,410	1,950
	0·5	93,000	15,300	6,575	2,260	1,990	2,450
2·5	0·1	560	195	135	140	210	445
	0·5	840	340	240	220	295	560
5·0	0·1	54	28·5	25	42·5	72·5	211·5
	0·5	81	50	45	67·5	102·5	265·5
10·0	0·1	10	7·5	8	18·5	40·5	125
	0·5	15	12·5	14	29	57·5	160

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TABLE V.

Power in kilowatts for $D = 5{,}000$ kilometres.

λ_m	β	$\gamma = 0{\cdot}5$	$\gamma = 0{\cdot}75$	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$
1·0	0·1	—	—	—	275,000	125,000	78,500
	0·5	—	—	—	435,000	177,000	99,000
2·5	0·1	330,000	43,500	16,600	5,600	5,200	6,800
	0·5	495,000	75,500	30,000	8,800	7,350	8,550
5·0	0·1	6,650	1,770	1,010	790	1,050	1,950
	0·5	10,000	3,085	1,820	1,250	1,485	2,450
10·0	0·1	405	180	145	195	335	805
	0·5	610	315	260	310	475	1,010

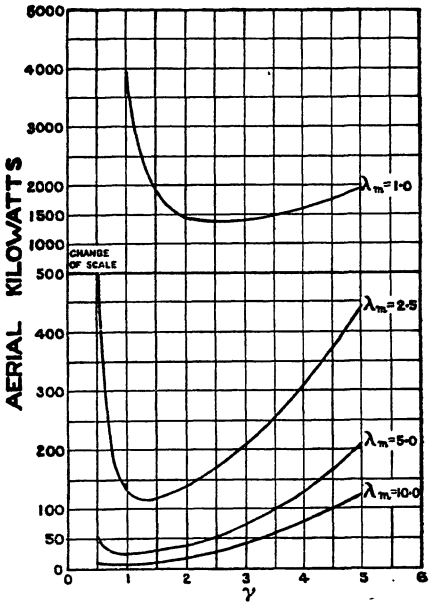

FIG. 4.

$D = 3{,}000$ kilometres; $\beta = 0{\cdot}1$.

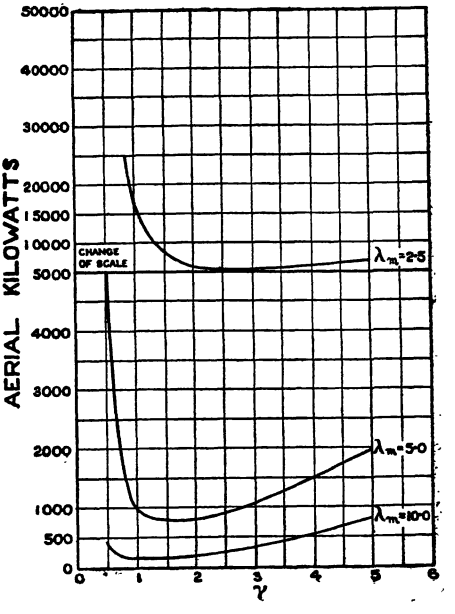

FIG. 5.

$D = 5{,}000$ kilometres; $\beta = 0{\cdot}1$.

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TABLE VI.

Power in kilowatts for $D = 10{,}000$ kilometres.

λ_m	β	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$
2·5	0·1	—	—	—	1,915,000
	0·5	—	—	—	2,410,000
5·0	0·1	—	365,000	202,500	156,500
	0·5	—	580,000	286,000	210,000
10·0	0·1	66,500	22,350	20,750	27,250
	0·5	120,000	35,300	29,400	34,300

It must be remembered that these figures are based upon the Austin-Cohen exponential factor, which is of uncertain application for distances greater than about 5,000 kilometres, and for wavelengths exceeding about 10 kilometres. We shall return to this aspect of the subject in our next number. Of less importance are the assumptions as to the constancy of the conductor resistance, and of the power-factor of the dielectric losses of the aerial.

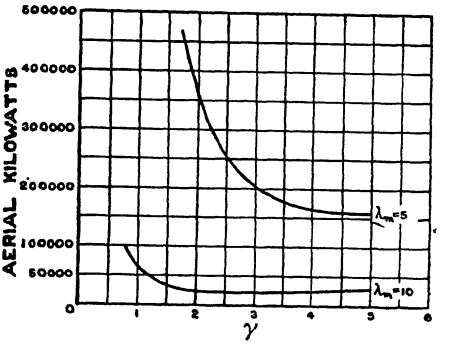

FIG. 6.

$D = 10{,}000$ kilometres; $\beta = 0{\cdot}1$.

The tables and curves bring out clearly the enormous saving of power which can be obtained by using aerials with high values of λ_m, that is with such small dielectric losses that the minimum total effective resistance is reached at long wavelengths.

Many of the very high values of P given in the tables are quite impracticable, since they could only be attained at impossibly high aerial voltages. They are given, however, to show the relation of the power actually employed to that which would be necessary to give signals of the assumed strength.

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For a given aerial and therefore a given value of λ_m, there is always a wavelength $\lambda = \gamma\lambda_m$ at which the power necessary for a given distance is a minimum. At longer wavelengths the inefficiency of the aerial more than counteracts the improved transmission. Table VII. shows the power P in kilowatts for various distances with aerials of different values of λ_m on the assumption that the wavelength is always chosen to require the minimum value of P, and that $\beta = 0{\cdot}1$. The wavelength is also given in each case.

TABLE VII.

The optimum wavelength in kilometres and the minimum power in kilowatts required to give 0·37 microvolts per cm. assuming the Austin-Cohen exponential factor.

D kms.	$\lambda_m = 0{\cdot}5$		$\lambda_m = 1$		$\lambda_m = 2{\cdot}5$		$\lambda_m = 5$		$\lambda_m = 10$	
	λ	P	λ	P	λ	P	λ	P	λ	P
1,000	0·5	3·5	0·9	0·9	1·75	0·27	2·5	0·134	5·0	0·076
2,000	1·15	430	1·5	70	2·4	9·0	4·0	2·7	7·5	1·1
3,000	2·5	10,500	2·5	1,400	3·5	117	5·0	25	8·5	7·3
5,000	—	—	6·0	75,000	7·0	5,100	8·75	770	12·5	150
10,000	—	—	—	—	—	—	25	157,000	30	20,000

These results are shown in Fig. 7 where the ordinates represent the logarithm of the power P in kilowatts. The actual values of P are indicated in the right-hand side of the figure. In Fig. 8 $\log_{10} P$ is plotted against $\log_{10} D$. If the power varied with the distance according to the law $P = mD^n$, we should have $\log P = \log m + n \log D$ and the curves of Fig. 8 would be straight lines. The slope of the curves gives the value of the index n, which is not a constant; its value at several points is indicated in Fig. 8.

The limiting factor in the amount of power which can be supplied to a given aerial is the voltage of the aerial at which, even if the insulators do not fail, the losses due to discharge from the wires increase very rapidly. This limiting voltage will depend on the size of wire employed and on the design of the insulators, etc., but for large well constructed aerials will probably be in the neighbourhood of 100,000 volts.

Since $I = 2\pi f V C$ where C is in farads
I in amperes
and V in volts

we have

$$V = 0{\cdot}53 \frac{I\lambda}{C'} = \frac{I\lambda}{2C'} \text{ kilovolts approximately.}$$

where C' is in milli-microfarads
and λ in kilometres.

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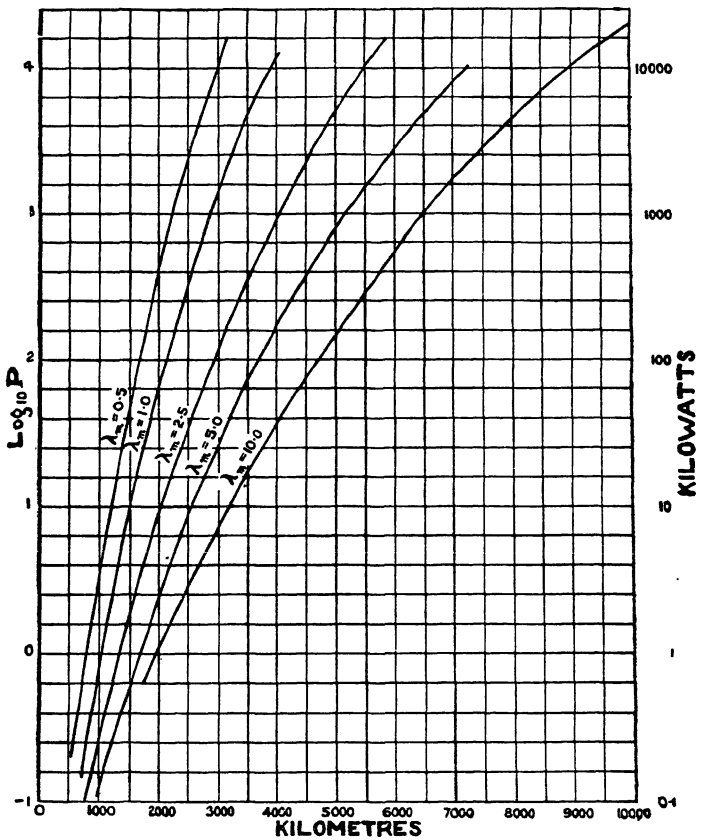

FIG. 7.

P is the power supplied to the aerial assuming the wavelength to have its optimum value in every case.

For example, if $C' = 12$ milli-microfarads

$\lambda = 11$ kilometres

and $I = 200$ amperes

$$V = 0{\cdot}53\,\frac{200 \times 11}{12} = 97 \text{ kilovolts.}$$

Since the power P in kilowatts is equal to $I^2R/1{,}000$, where R is the total effective resistance at the working wavelength, $I = \sqrt{\frac{1{,}000P}{R}}$ and

$$V = 17\,\frac{\lambda}{C'}\sqrt{\frac{P}{R}} \text{ . kilovolts.}$$

It is therefore a simple matter to see whether any power P can be supplied

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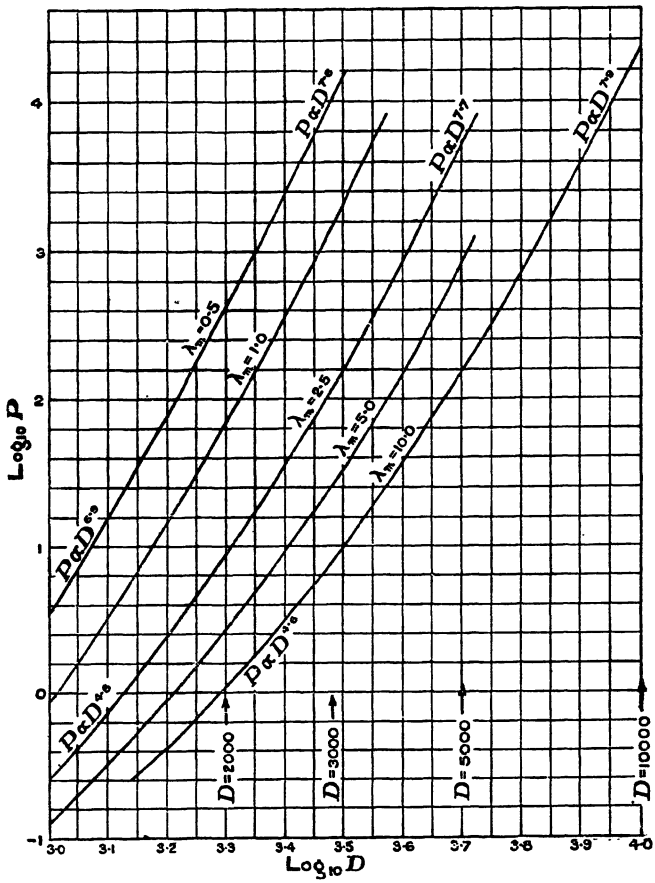

FIG. 8.

at a given wavelength to an aerial of known capacity and resistance without exceeding the permissible voltage. Conversely, from the formula

$$P = \frac{C'^2 V^2 R}{280\lambda^2} \text{ kilowatts}$$

one can calculate the power corresponding to a given value of V. For example, if $C' = 12$ milli-microfarads, $V = 100$ kilovolts, $R = 3{\cdot}75$ ohms and $\lambda = 11$ kilometres (these values apply approximately to the San Paolo, Rome, aerial) we have as the maximum power

$$P = \frac{144 \times 10^4 \times 3{\cdot}75}{280 \times 121} = 160 \text{ kilowatts.}$$

Hence in some cases it may be inadvisable to work at the optimum wavelength given in Table VII. and one may be compelled to use a shorter wavelength and consequently more power than that given in Table VII. in order to keep the aerial voltage within the prescribed limits.

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Review of Radio Literature.

1. Articles and Patents.

748. ON THE ELECTRICAL CHARACTERISTICS OF LOW ANTENNÆ. R. Jaeger. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 318—321, April, 1920.)

The electrical characteristics of high antennæ are on the whole fairly constant and not affected to any great extent by the condition of the weather. This is not the case with cable antennæ lying on the ground and thus measurements of the usual characteristics, *e.g.*, natural wavelength, decrement and capacity, must be made for different ground conditions. This has been done for a variety of earth antennæ and also for certain types of low aerials. The natural wavelength was measured by joining the two ends of the cable through a coil possessing a small inductance and exciting the completed circuit with a Telefunken buzzer wavemeter. Resonance was detected by a loosely coupled aperiodic detector circuit. The decrement was determined by an oscillating valve method due to Brandes. The main result of the measurements is to show that an enormous increase in decrement is experienced during and shortly after rain. The natural wavelength and capacity are also altered in such cases. The decrement of a polished copper earth antenna on dry ground was greater than that of a corresponding insulated cable antenna but was smaller when laid on brushwood-covered earth.

A summary of the main results is given in the accompanying table :—

Type of Antenna.	Natural Wave-length.	Decre-ment.	Wave-length (metres)	Capacity (in cms.).	Weather.
Two-legged Cable Antenna .	255	0·133	700	500—600	Dry.
	255	0·329	300	500—600	Dry.
	255	0·245	700	500—600	Wet.
	255	0·640	300	500—600	Very wet.
T-Cable Antenna . . .	300	0·150	700	600	Dry.
	300	0·366	300	600	Dry.
Low Antenna (Height 2 m.) .	—	0·077	700	—	Dry.
	—	0·150	300	—	Dry.
Two-legged Bare Copper Antenna.	—	0·215	700	345	On dry ground.
	—	0·141	547	225	On brushwood.

749. THEORY OF ANTENNA RESISTANCE. W. H. Eccles. (*Electrician*, 84, p. 370, April 2nd, 1920. *Technical Review*, 6, p. 467, May 25th, 1920—Abstract. *Science Abstracts*, 23B, pp. 277—278, Abstract No. 547, May 31st, 1920—Abstract.)

The author quotes Heaviside's theory dealing with the manner in which the Faraday lines

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attached to the electric charges move up and down the antenna so that a fraction of the moving lines is detached at each oscillation.

The total current I in the antenna is assumed to be divided into two portions i and j, the former being devoted to heating the conductors of the aerial and the latter being concerned with the radiation. The ratio j/I may be taken to vary approximately as the first power of the oscillation frequency f, that is $j/I = af$, from which it is shown that the total power expended in the aerial circuit may be written as

$$P = ri^2 + mj^2$$
$$= \{r - 2raf + (r + m)\, a^2f^2\}\, I^2$$

The quantity within the brackets therefore represents the antenna resistance, and this is shown to have a minimum value of $rm/(r + m)$ when $af = r/(r + m)$.

The values given by this equation have been found to agree fairly well with measurements made on aerials, and with the variation of the antenna resistance with the wavelength.

750. ALTERNATING CURRENT WORK WITH REFERENCE TO THE THREE-ELECTRODE VALVE. R. C. Clinker. (*Wireless World*, 8, pp. 30—32, April 3rd, 1920; pp. 67—68, April 17th, 1920; pp. 102—104, May 1st, 1920. *Technical Review*, 6, p. 507, June 8th; and p. 549, June 22nd, 1920—Abstract.)

The author treats of several of the usual types of wireless circuits by means of vector algebra and equations of the type customarily employed for ordinary alternating current problems. Various coupled valve circuits are included.

751. THE SKIN EFFECT AND FLUX DISTRIBUTION OF CONDUCTORS IN PROXIMITY TO IRON. A. Press. (*Physical Review*, 15, pp. 450—453, May, 1920.)

The author describes some experiments tending to prove that the flux distribution and therefore the skin effect of conductors in iron slots or in proximity to iron approximates very closely to the distribution and skin effect for the same conductors in free air. The solutions previously obtained for windings in air both for low and high frequencies are therefore also applicable to these cases.

752. UNILATERAL CONDUCTIVITY IN CRYSTALS. F. Streintz and A. Wesely (*Physikalische Zeitschrift*, 21, pp. 42—50, January 15th, 1920. *Elektrotechnische Zeitschrift*, 41, p. 400, May 20th, 1920—Abstract. *Science Abstracts*, 23A, pp. 357—358, Abstract No. 912, June 30th, 1920—Abstract.)

A theoretical and experimental paper supporting the view that unilateral conductivity is not due to electrolytic action in liquid films, but is due to the presence of gas films. It is not clear, however, how the gas film causes the unilateral conductivity.

753. DAMPED OSCILLATIONS IN COUPLED CIRCUITS. G. B. Ehrenborg. (*Technical Review*, 6, pp. 264, 467 and 506, March 16th, May 25th, June 8th, 1920—Abstracts. *Science Abstracts*, 23A, pp. 356—357, Abstract No. 910, June 30th, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 220—224, February, 1920; pp. 329—336, April, 1920; pp. 375—380, May 1920, for the original article.

754. RADIO TUNING CIRCUITS. (*Everyday Engineering Magazine*, 9, pp. 160—161, May, 1920.)

Treats of radio circuits from the view-point of ordinary alternating current reactance and impedance formulæ.

755. DIFFICULTIES IN THE TRANSMISSION AND RECEPTION OF SUSTAINED WAVES. M. Wien. (*Science Abstracts*, 23B, p. 111, Abstract No. 211, February, 1920—Abstract.)

See RADIO REVIEW Abstract No. 271, April, 1920.

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756. THE DESIGN OF POULSEN ARC CONVERTERS FOR RADIOTELEGRAPHY. L. F. Fuller. (*Science Abstracts*, 23B, p. 66, Abstract No. 133, January, 1920—Abstract. *L'Elettrotecnica*, 7, pp. 189—191, April 15th, 1920—Abstract.)
See RADIO REVIEW Abstract No. 398, June, 1920.

757. ON THE SELF-INDUCTANCE OF SINGLE LAYER FLAT COILS. S. Butterworth. (*Science Abstracts*, 23A, p. 164, Abstract No. 435—Abstract. *Revue Générale de l'Électricité*, 7, p. 164D, May 22nd, 1920—Abstract.)
See RADIO REVIEW Abstract No. 400, June, 1920.

758. ON THE PHENOMENA PRODUCED BY THE INTERRUPTION OF A STEADY CURRENT IN AN OSCILLATORY CIRCUIT. G. Zickner. (*Science Abstracts*, 23B, p. 197, Abstract No. 392, April, 1920—Abstract.)
See RADIO REVIEW Abstract No. 270, April, 1920.

759. THE CALCULATION OF THE SELF-INDUCTANCE OF RECTANGULAR FLAT COILS. A. Esau. (*Science Abstracts*, 23A, p. 164, Abstract No. 434, March, 1920—Abstract.)
See RADIO REVIEW, 1, Abstract No. 272, April, 1920.

760. PRINCIPLES OF RADIO TRANSMISSION AND RECEPTION WITH ANTENNÆ AND COIL AERIALS. J. H. Dellinger. (*Science Abstracts*, 23B, pp. 65—66, Abstract No. 132, January, 1920—Abstract. *Scientific American*, 122, p. 669, July 19th, 1920—Abstract.)
See RADIO REVIEW Abstract No. 399, June, 1920.

761. ON THE THEORY OF RADIOTELEGRAPHIC AND RADIOTELEPHONIC RECEIVER CIRCUITS. J. F. J. Bethenod. (*Science Abstracts*, 23B, p. 66, Abstract No. 134, January, 1920—Abstract.)
See RADIO REVIEW Abstract No. 398, June, 1920.

762. DETERMINATION OF RATE OF DE-IONISATION OF ELECTRIC ARC VAPOUR. H. G. Cordes. (*Science Abstracts*, 23A, p. 94, Abstract No. 254, February, 1920—Abstract.)
See RADIO REVIEW Abstract No. 397, June, 1920.

763. THERMO-COUPLES FOR ELECTRICAL MEASUREMENTS. J. L. Weatherwax. (*British Patent* 139486, February 25th, 1920. Convention date, February 27th, 1919. Patent not yet accepted but open to inspection.)

Thermo-couples for electrical measurement purposes are described having a heater wire of nickel steel and a thermo-couple constructed between wires of iron and of nickel-copper-alloy containing no zinc. The containing vessel is filled with an inert gas of high thermal conductivity such as hydrogen, argon, nitrogen, etc.

764. DETERMINATION OF DISTRIBUTED CAPACITY AND INDUCTANCE OF A COIL. (*Everyday Engineering Magazine*, 7, p. 158, May, 1920.)

The usual resonance method is described.

765. A DIFFERENTIAL METHOD OF MEASURING CAPACITY AND INDUCTANCE WITH A SENSIBILITY OF 2×10^{-8}. G. Falckenberg. (*Annalen der Physik*, 61, pp. 167—172, January 15th, 1920. *Science Abstracts*, 23A, p. 290, Abstract No. 745, May 31st, 1920—Abstract.)

A thermionic valve oscillator induces current in two independent tuned oscillatory circuits, one of which contains the condenser or inductance under test. These two circuits are coupled to a common tuned tertiary circuit but in opposition so that their joint effect can be reduced to zero. This adjustment is then very sensitive to any variation of the capacity or inductance in one of the intermediate circuits. The condenser in the tertiary circuit is connected to the grid of a two-valve amplifier and a galvanometer is connected across a resistance in the anode

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circuit of the second valve, a battery being inserted to compensate for the steady voltage across this resistance. At a frequency of 11,000 with a total capacity of 2,500 cms. one could detect a variation of 0·02 part in a million.

766. A NEW AUDIO-FREQUENCY METER FOR WEAK CURRENTS. K. Wolff. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 321—326, April, 1920.)

A compensation device of the Campbell type in which the alternating current from a source K (the frequency of which is to be measured) passes through the coil L_1 and capacity C (see Fig. 1). If the mutual inductance M is adjusted so that the sound in the telephone T is a minimum the frequency n is given by the equation $n = 1/2\pi\sqrt{MC}$. Details are given of the design of a compact calibrated instrument made by Seibt suitable for frequencies between 450 and 1,200 per second.

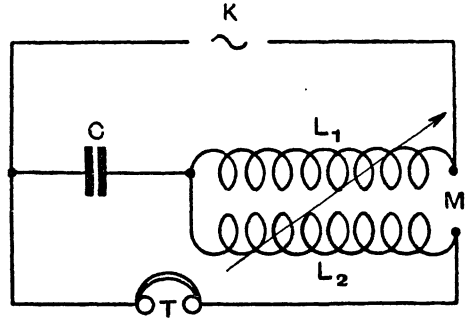

FIG. 1.

767. MEASUREMENT AND COMPARISON OF SIGNAL INTENSITIES IN WIRELESS RECEIVERS. H. de Bellescise. (*Science Abstracts*, 23B, p. 221, Abstract No. 431, April, 1920—Abstract. *Technical Review*, 6, p. 466, May 25th, 1920—Abstract. *Telegraphen- und Fernsprech-Technik*, 9, pp. 18—19, April, 1920—Abstract. *Electrical World*, 76, p. 136, July 17th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 331, May, 1920.

768. A METHOD FOR MEASURING VERY SMALL CAPACITIES AND INDUCTANCES. L. Pungs and G. Preuner. (*Science Abstracts*, 23A, pp. 242—243, Abstract No. 618, April, 1920—Abstract. *Elektrotechnische Zeitschrift*, 41, p. 398, May 20th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 403, June, 1920.

769. THE USE OF AMPLIFIERS FOR MEASURING SMALL DIFFERENCES OF POTENTIAL. A. Blondel. (*Science Abstracts*, 23B, p. 87, Abstract No. 165, February, 1920—Abstract.)

See RADIO REVIEW Abstract No. 186, February, 1920.

770. THE USE OF AMPLIFIERS FOR THE MEASUREMENT OF SMALL DIFFERENCES OF POTENTIAL. R. Depriester. (*Science Abstracts*, 23B, pp. 137—138, Abstract No. 275, March, 1920—Abstract.)

See RADIO REVIEW Abstract No. 212, March, 1920.

771. THE NEW KOLSTER DECREMETER AND WAVEMETER. (*Electrical Experimenter*, 7, p. 663, November, 1919.)

An illustrated description of the apparatus together with instructions for its use.*

* The original description of this instrument may be found in the *Proceedings of the Institute of Radio Engineers*, 3, pp. 29—53, March, 1915.

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772. PRODUCING ELECTRIC OSCILLATIONS. R. B. Goldschmidt. (*British Patent* 138366, January 30th, 1920. Convention date, November 18th, 1913. Patent not yet accepted but open to inspection.)

In the usual arrangement of quenched spark transmitters for shock excitation the oscillations in the primary are quenched out by the resistance of the spark gap. In the arrangement here described this quenching is provided by an inductively coupled energy consuming circuit, or by an arrangement for dissipating the energy in the form of hysteresis or eddy current losses in masses of metal. The characteristics of the damping circuits are chosen so that the absorption of power is delayed until after the first maximum amplitude of the primary current.

773. A NEW RADIOTELEGRAPHIC INVENTION. (*Elektrotechnische Zeitschrift*, 40, p. 569, November 6th, 1919. *Revue Générale de l'Électricité*, 7, p. 156D, May 15th, 1920—Abstract.)

Reference is made to an apparatus due to Petersen in which the electric oscillations are obtained by the discharge of condensers without employing a spark gap. It is claimed that a good musical note may be obtained, but no technical details are given.

774. THE POULSEN SYSTEM OF RADIOTELEGRAPHY: HISTORY OF DEVELOPMENT OF ARC METHODS. C. F. Elwell. (*Electrician*, 84, pp. 596—599, May 28th, 1920. *Science Abstracts*, 23B, p. 278, Abstract No. 548, May 31st, 1920—Abstract. *Technical Review*, 6, p. 659, August 3rd, 1920—Abstract.)

The history of the early work on the Poulsen arc starting from Poulsen's first discovery in 1902 is briefly outlined in this article, and the various stations that have been erected by the various companies concerned and by the author of the article are briefly mentioned including a more detailed and illustrated description of the plant at the Honolulu and Arlington stations. Reference is also made to the more recently erected installations at Horsea, Eiffel Tower, Lyons, Rome, Nantes and the stations at present under construction at Leafield and Cairo.

775. A SMALL POULSEN GENERATOR FOR LABORATORY MEASUREMENTS. M. Giddemeister. (*Science Abstracts*, 23A, pp. 96—97, Abstract No. 260, February, 1920—Abstract. *Revue Générale de l'Électricité*, 7, p. 133D, April 24th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 408, June, 1920.

776. AN ELECTRON TUBE TRANSMITTER OF COMPLETELY MODULATED WAVES. L. M. Hull. (*Journal of the Washington Academy of Sciences*, 10, pp. 316—323, June 4th, 1920. *Nature*, 105, pp. 624 625, July 16th, 1920—Abstract.)

The author describes a three-electrode valve transmitter using a low voltage alternating current for heating the filament, and high voltage A.C. from the same source for supplying the plate voltage. By this means a complete modulation of the antenna current from zero to the maximum is obtained at an audible frequency, thus rendering the set suitable for use with non-oscillating receiving circuits for at least limited ranges. A circuit diagram of the arrangement is given together with dimensions of many of the parts for a set using a 500 cycle supply at 150 volts. The author shows that the power output in the antenna is inversely proportional to the product of the antenna capacity and antenna resistance, and that therefore it may be difficult with a given antenna to obtain the maximum output from the tube at short wavelengths if the antenna resistance is low. In the set referred to in the article an overall efficiency of 35 per cent. from the alternator terminals to the antenna was obtained, this figure including the filament heating losses.

An instructive comparison is given between the wave forms of the aerial current arising from such a set supplied with sine wave alternating current in the plate circuit, and the wave form of the aerial current from a spark transmitter. For the same antenna current at a wavelength of 535 metres and with 500 wave-trains per second it is shown that the maximum voltage in the case of the spark transmitter is about thirteen times the maximum voltage with the modulated C.W. transmitter if the decrement of the oscillations in the case of the spark is 0·089, from which it is at once evident that a crystal detector should give a louder response to signals from the spark set.

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777. THERMIONIC VALVE OSCILLATION GENERATORS. E. H. Colpitts. (*British Patent*, 141060, March 31st, 1920. Convention date, February 1st, 1918. Patent not yet accepted but open to inspection.)

The so-called "Colpitts" oscillation generator circuit is described in this specification. The arrangement is indicated in Fig. 2, which shows a single inductance L connected between the plate and grid of the valve in the oscillation circuit, the condensers C_1 and C_2 being connected in series as shown, while the leak resistance R is to ensure that the grid potential remains the same as that of the filament. The condenser C is merely for blocking purposes. For transmission purposes the aerial circuit may be coupled at T as indicated or alternatively the capacity C_1 may be replaced by the aerial capacity, the filament of the valve being connected to earth so that the condenser C_2 forms part of the aerial circuit.

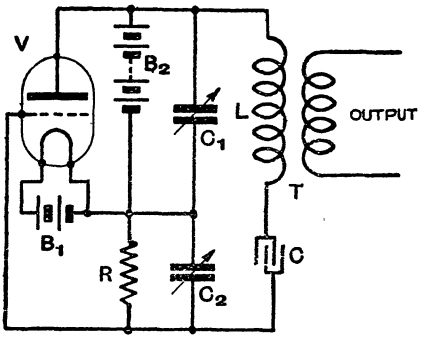

FIG. 2.

778. EDUCATIONAL APPARATUS FOR CONTINUOUS WAVE SENDING AND RECEIVING. (*Telefunken Zeitung*, 3, No. 18, pp. 75—77, October, 1919.)

An illustrated description of a board with all the various valve circuits and accessories plainly shown and labelled.

779. HIGH-FREQUENCY ALTERNATOR OR ARC GENERATOR? (*Telefunken Zeitung*, 4, No. 20, pp. 16—18, May, 1920.)

An article written to show that the former method is superior to the latter.

780. HIGH FREQUENCY INDUCTOR ALTERNATORS. O. Billieux. (*British Patent* 140769, March 22nd, 1920. Convention date, November 22nd, 1917; and *British Patent* 140773, March 22nd, 1920. Convention date, January 24th, 1918. Patents not yet accepted but open to inspection.)

Various arrangements of high frequency alternators are described, in particular ones involving the use of two discs rotating at equal speeds in opposite directions and provided with magnetic teeth interspersed with non-magnetic teeth around their periphery. A single homopolar winding may be provided on the stator together with an armature winding around the stator teeth which face the teeth of each rotating disc. Alternatively when the width of the teeth is equal to the width of the space between them a variable reluctance type of machine is obtained so that the field winding may be dispensed with and the armature winding used for the excitation as well as for the high frequency current. Various special arrangements of teeth are also described leading to modifications of the machine and in one case with the suppression of the stator entirely and with the use of an exciting winding mounted on one of the rotating discs. See also RADIO REVIEW Abstract No. 410, June, 1920.

781. HIGH-FREQUENCY ALTERNATORS. M. Latour. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 220—237, June, 1920. *Electrical World*, 76, p. 33, June 3rd, 1920—Abstract.)

Partly a reproduction of a communication presented to the Société Française des Électriciens.*

See also RADIO REVIEW, 1, p. 491, July, 1920, where a lecture covering the same subject-matter has been abstracted.

* *Bulletin de la Société Francaise des Électriciens*, 9, pp. 97—114, February, 1919.

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782. MODERN RADIO TRANSMITTERS OF UNDAMPED OSCILLATIONS. G. von Arco. (*Science Abstracts*, 23B, p. 163, Abstract No. 329, March, 1920—Abstract.)
See RADIO REVIEW Abstract No. 281, April, 1920.

783. HIGH FREQUENCY TELEPHONY. G. Beauvais. (*La T.S.F. Moderne*, 1, pp. 4—7, April, 1920.)
The application of radio telephone transmitters to communication along telephone lines using high frequency carrier currents is dealt with, and in particular a method of modulation in which the modulating valve V_1 is connected in parallel with the grid condenser C of the oscillating valve V_2. It thus replaces the grid leak by the controlled plate-filament resistance of the modulating valve. See Fig. 3.

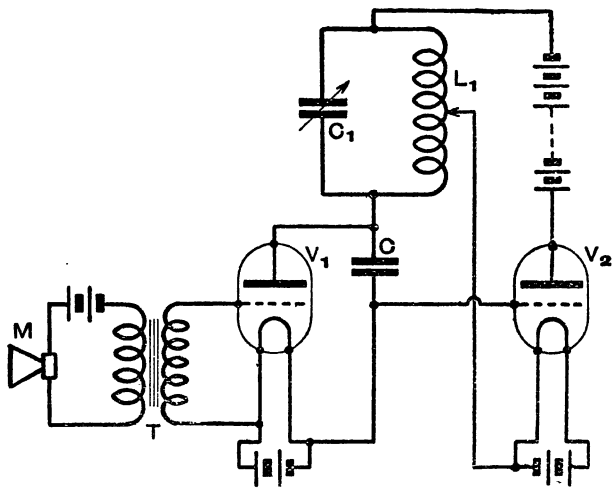

FIG. 3.

784. MODULATION ARRANGEMENTS FOR THERMIONIC OSCILLATION GENERATORS. E. H. Colpitts. (*British Patent* 141047, March 30th, 1920. Convention date, May 8th, 1914. Patent not yet accepted but open to inspection.)
In a thermionic valve oscillation generator provided with a retro-active coupling between the anode and the grid circuits modulation of the high frequency oscillations is arranged by means of a microphone coupled between the grid and filament of the valve and hence in parallel with the retro-active coupling. Other modifications are described whereby two or more valves may be used to increase the output.

785. APPLICATION OF THERMIONIC AMPLIFIERS AS TELEPHONIC REPEATERS. C. Robinson and R. M. Chamney. (*Institution of Post Office Electrical Engineers*, Paper No. 76, pp. 1—128, 1919. *Science Abstracts*, 23B, p. 174, Abstract No. 349, March, 1920.)
The first of these two papers describes the work done in the British Post Office on this subject up to 1917. After an outline of conduction through gases the authors give details of the Cooper Hewitt and the Lieben magnetically controlled tubes and accounts of the Audion, the Lieben-Reisz relay, the Round tube, the Pliotron with particulars of tubes developed by the Post Office. Experimental methods and results are described.
The second paper describes the development since 1917. After a reference to the theory of

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the "hard" tube the authors state that this type has now replaced the soft type, the pattern now used being that known as the French valve. Complete characteristics are given for this type and its performance is discussed in detail. Equations for determining the magnification effected are given. The determination of the best ratio for the transformers is discussed and particulars are supplied of the variation of the magnification with transformation ratio, with grid and plate voltages and with the input.

786. TELEPHONE TRANSMITTERS. B. F. Miessner. (*British Patent* 140070, March 8th, 1920. Convention date, March 12th, 1919. Patent not yet accepted but open to inspection.)

A microphone transmitter is described particularly adapted for use on aircraft. The diaphragm casing is arranged so that the diaphragm itself is equally exposed on both sides. Engine noises, etc., may thus be eliminated whilst speech which impinges on one side of the diaphragm only is transmitted.

787. TELEPHONE REPEATERS. M. Latour. (*British Patent* 140123, September 5th, 1918. Convention date, September 5th, 1917. Also *British Patent* 140133, October 26th, 1918. Convention date, October 3rd, 1917. Patents accepted March 25th, 1920.)

These specifications deal with three-electrode valve amplifiers for telephone lines in which the filament is switched on and off by a relay operated by the calling signal. Means may also be provided for indicating at the operators' stations when the filament circuit of the relay has been opened.

788. TRANSMITTING SYSTEM. Société le Matériel Téléphonique. (*French Patent* 500655, June 12th, 1919. Published March 20th, 1920.)

In a method of modulating high frequency carrier oscillations, the carrier oscillations are impressed symmetrically on a pair of circuits which are influenced differentially by the signal currents, the modulated oscillations being impressed differentially on the out-going circuits. For further particulars, see British Patent 130219.*

789. WIRELESS TELEPHONY AND RAILWAY STRIKES. (*Wireless World*, 8, p. 23, April 3rd, 1920.)

An account is given of a wireless telephone network set up between London, Wellingboro', Birmingham, Leicester, Derby, Rotherham and Leeds during the railway strike of September and October, 1919, in order to ensure a reliable means of communication between those places.

790. AN OSCILLION RADIO TELEPHONE AND TELEGRAPH. (*Electrical Experimenter*, 7, pp. 908 and 954, January, 1920.)

A panel type radio telephone set manufactured by the de Forest Radio Company is described and illustrated.

791. THE PRESENT POSITION OF WIRELESS TELEPHONY. K. Heffner. (*Telefunken Zeitung*, 3, No. 18, pp. 67—72, October, 1919.)

A description of the methods of duplex telephony and a discussion of the relative advantages of wire and wireless methods.

792. TRANSATLANTIC WIRELESS TELEPHONY. J. A. Fleming. (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 177—178, March, 1920.)

See RADIO REVIEW Abstract No. 135, January, 1920.

793. SIMULTANEOUS TRANSMISSION AND RECEPTION IN RADIOTELEPHONY. N. Marumo. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 199—219, June, 1920. *Electrical World*, 76, p. 86, July 10th, 1920—Abstract.)

In attacking the problem of simultaneous transmission and reception, great difficulty is

* RADIO REVIEW Abstract No. 35, November, 1919.

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experienced in excluding induction into the receiving circuit from its own transmitter. Until recently the only practical duplex system seems to have been that of the Marconi Company in which the sending and receiving stations must be several miles apart. Recently a method has been devised by Dr. W. Torikata and his staff in the Imperial Japanese Electro-Technical Laboratory, Tokyo, in which only one antenna is required. The arrangement which can also be adapted to " wired wireless " is illustrated in Fig. 4.

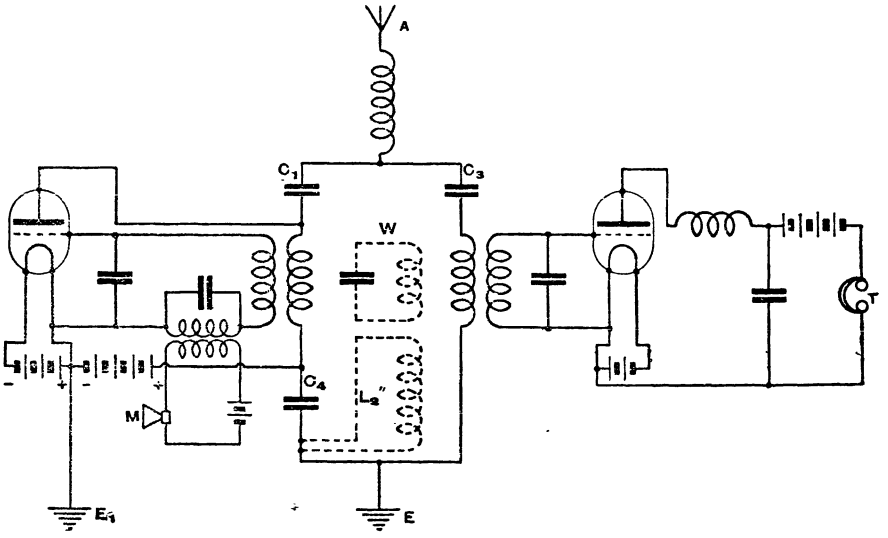

FIG. 4.

The antenna is of the divided branch type with a supplementary balancing coil L_2'' and absorbing circuit W for use if necessary. The sending wavelength is adjusted to one of the natural wavelengths of the system and the receiving wavelength to the other. The impedances of the three branches of the antenna circuit are adjusted (*a*) to minimise the current flowing in the receiving branch due to the sending current and (*b*) to make the externally received current as large as possible. The conditions for obtaining these desiderata are investigated mathematically, but even though the adjustments so indicated are made it is practically impossible to get rid of the effect of the transmitter on the receiver without the use of the balancing coil.

Full diagrams of applications of the above circuit to combined wired wave telephony and telegraphy are given in which the use of a single oscillation generator for a number of stations is shown to be possible.

794. DUPLEX WIRELESS SIGNALLING. R. Whiddington and P. P. Eckersley. (*British Patent* 134341, November 4th, 1918. Patent accepted November 4th, 1919.)

The arrangement consists in providing the receiving aerial with two branches one of which contains a capacity and inductance to tune it to the frequency of the signal to be received and the other containing a capacity only so that its impedance is different to that of the first branch. Oscillations of frequency differing from those which it is desired to receive will then pass to earth by the second branch having the smaller impedance and so will not affect the receiver which is coupled to the inductance of the first branch. The arrangement is particularly applicable for preventing interference from the adjacent transmitter in duplex work.*

* See also RADIO REVIEW Abstract No. 492, July, 1920, where a somewhat similar duplex arrangement is described.

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795. A NEW AUTOMATIC TELEGRAPH. (*Electrician*, 85, p. 62, July 9th, 1920.)

A new automatic transmitting apparatus for wireless or ordinary telegraph purposes is briefly described and illustrated. The apparatus is provided with a single plug and with sixty jacks into any one of which the plug may be inserted. Each jack is provided with a name plate indicating the particular signal to which it refers. To operate the apparatus the plug is inserted into the jack corresponding to the message that it is desired to send and a lever at the side is pressed down, when that message will be transmitted automatically prefixed by the code letter or number of the instrument. Provision is also made for the transmission of "S.O.S." messages. The arrangement is particularly suitable for use on aircraft and also for small vessels not carrying a certificated wireless operator.

796. VACUUM TUBES. Siemens and Halske Akt.-Ges. (*British Patent* 134542, October 30th, 1919. Convention date, June 21st, 1916. Patent not yet accepted but open to inspection.)

In the arrangement described two intermediate electrodes are interposed between the filament and the plate and the valve, one of them being maintained at a negative potential and the other at a positive one. The suggested arrangement is indicated in Fig. 5 in which F is the filament and P the plate while the zig-zag shown in end view at G_1 forms one of the intermediate electrodes which is placed inside the second intermediate electrode G_2 which is in the form of a wire grid wound round the glass rod support A B. The plate P may also be mechanically supported from this glass rod frame as indicated.

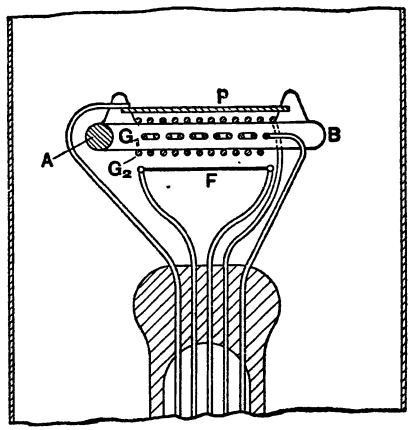

FIG. 5.

797. VACUUM TUBES. G. Holst and E. Oosterhuis. (*British Patent* 137281, December 22nd, 1919. Convention date, December 31st, 1918. Patent not yet accepted but open to inspection.)

It is suggested that the anode for a thermionic valve for generating oscillations should be made hollow so that water or gas may be circulated through the inner hollow space. An electric heater may also be inserted to expel gases from the material of the anode during exhaustion of the valve.

798. ELECTRONIC AND IONIC OSCILLATIONS IN THERMIONIC VALVES. G. W. O. Howe. (*Technical Review*, 6, p. 690, August 17th, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 434—436, June, 1920.

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799. SOME NOTES ON VACUUM TUBES. J. H. Morecroft. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 239—260, June, 1920. *Electrical World*, 76, p. 33, July 3rd, 1920—Abstract.)

An attempt to reconcile the experimentally obtained characteristics of vacuum tubes with the general theory as developed by Langmuir, van der Bijl and others. The general expression for the anode current I_p of a tube is

$$I_p = \alpha (E_p + \mu_0 E_g + \epsilon)^x$$

where E_p and E_g are the anode and grid voltages respectively and α, μ_0, ϵ and x are constants. One of the factors which determine the value of ϵ is the electronic emission velocity which, increasing with increase of temperature, is evidently greater for tungsten filaments than for oxide filaments. To find how ϵ varied with the temperature the relation between filament current and anode current in a diode was obtained for zero anode voltage (the anode being connected to the negative end of the filament). The anode current increased rapidly with increase of filament temperature but was shown to be extremely small compared with the current obtained when the anode voltage is increased to unity.

The value of the exponent x has been given as $\frac{3}{2}$ and 2, the former a theoretically derived value and the latter experimentally obtained. For certain low anode voltage tubes it is shown that not only does the value not lie between $\frac{3}{2}$ and 2 but that it also varies with the anode voltage, decreasing with increase of the latter. One of the principal reasons for the variation of the exponent is that there are different voltages between different parts of the filament and the anode since the large change in x does not occur if the surface emitting the electrons is an equipotential surface.*

The distortion effect in an amplifier tube has been considered by van der Bijl who showed that for an impressed grid E.M.F. of $E_g \sin \omega t$,

$$I_p = \alpha (\tau E_p + E_c + \epsilon)^2 + 2\alpha (\tau E_p + E_c + \epsilon) E_g \sin \omega t + \frac{\alpha E_g^2}{2}(\cos 2\omega t + \pi) + \frac{\alpha E_g^2}{2}.$$

The third term represents distortion and may be made as small as desired by adding sufficient resistance in the anode circuit. As the coefficient of the third and fourth terms are the same and as the latter is shown on a direct current instrument in the anode circuit, the distortion can be determined. To do this the variation between D.C. instrument reading and impressed sinusoidal grid voltage was determined. The effect of adding resistance in the anode circuit was found to be in accordance with van der Bijl's theoretical discussion.

The internal capacities and conductances of a number of tubes were measured by a Wheatstone bridge method. The capacities were found to depend on the connections of the electrodes and were found to be within the following ranges :—

	Capacity in micro-microfarads.
Grid to filament, anode free	10·4 to 55·6
Grid to plate, filament free	14·4 to 22·0
Grid to plate and filament, these being connected together.	17·0 to 69·6

Only the smallest increases in these capacities were found when the filament was heated. If one side of the filament is earthed the capacity of the grid-ground circuit, when the tube is operating with a normal amount of resistance or reactance in the anode circuit is from 5 to 10 times as much as the geometrical capacity of this circuit, and the amount of this increase is controlled by the capacity between the grid and plate.

* See *Physical Review*, 8, p. 563.

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Some experiments on the detecting action of a tube without grid condenser seem to prove that the asymmetry of the grid-filament circuit plays an unimportant part in this action.

800. ON THE THEORY OF IONISATION BY COLLISION. P. O. Pedersen. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 289—299, April, 1920. *Philosophical Magazine*, 40, pp. 129—137, July, 1920.)

A theoretical discussion of the case of the ionisation produced by collision in gas between two parallel electrodes. Various corrections are made in the theory originally given by Townsend. The latter from his experiments on atmospheric air had deduced a value of 20 volts for the ionising potential. The same experimental results with the corrected theory yield the value of 16 volts which is nearer the value of 10 volts obtained by Franck and Hertz by the more direct method.

The main assumptions in the present treatment (originally due to N. R. Campbell who failed to give an exact solution) are as follows :—

(*a*) An electron will produce a fresh pair of ions when colliding with a neutral molecule if previous to the collision its velocity v satisfies the relation

$$v \geqq v_0 = \sqrt{\frac{2e}{m}} \cdot V_0$$

where e/m is the ratio of charge to mass of the electron, and V_0 a constant voltage for the particular neutral molecules.

(*b*) Collisions between electrons and molecules take place unelastically so that the velocity of the electron after the collision is zero.

(*c*) The velocity of the liberated electrons is zero.

(*d*) The velocity of the electrons due to the electric field is so great that the thermal velocities of the electrons and the molecules may be disregarded.

801. IONIC OSCILLATIONS IN THREE-ELECTRODE THERMIONIC VALVES. R. Whiddington. (*Science Abstracts*, 23B, p. 69, Abstract No. 140, January, 1920—Abstract.)

See RADIO REVIEW Abstract No. 427, June, 1920.

802. THE VACUUM TUBE AS A GENERATOR OF ALTERNATING CURRENT POWER. J. H. Morecroft and H. T. Friis. (*Science Abstracts*, 23B, p. 67, Abstract No. 136, January, 1920—Abstract. *Revue Générale de l'Électricité*, 7, p. 198D, June 19th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 417, June, 1920.

803. DETERMINATION OF THE OUTPUT CHARACTERISTICS OF ELECTRON TUBE GENERATORS. L. M. Hull. (*Science Abstracts*, 23B, p. 111, Abstract No. 209, February, 1920—Abstract. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 70—71, July, 1920—Abstract. *Electrical World*, 76, p. 137, July 12th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 420, June, 1920.

804. AMPLIFICATION CONSTANTS AND INTERNAL RESISTANCES OF THREE-ELECTRODE VALVES. J. M. Miller. (*Technical Review*, 6, p. 548, June 22nd, 1920—Abstract.)

See RADIO REVIEW, 1, p. 454, Abstract No. 426, June, 1920.

805. THE THERMIONIC VALVE IN WIRELESS TELEGRAPHY AND TELEPHONY. J. A. Fleming. (*Engineering*, 109, p. 760, June 4th, 1920. *Electrician*, 84, p. 646, June 11th, 1920—Abstract.)

Abstract of lecture delivered at the Royal Institution on May 21st, 1920. The lecturer briefly reviewed the development of the two- and three-electrode valves from the early experiments on the Edison effect and led up to its modern use in wireless work. A special four-anode valve was also described for use as a call device in wireless reception. The four anodes surrounded a central filament which was heated by a battery and two of them were connected across a resistance of 20,000 ohms joined in the plate circuit of a detecting valve coupled to the receiving aerial. The remaining two anodes at right angles to the others were connected together and in series with a relay to the positive terminal of the filament heating

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battery. When a signal is received the plate current of the detecting valve is decreased with the result that a current is enabled to flow to two of the anodes of the special valve thus operating the relay.

806 VACUUM-TUBE CIRCUITS. P. H. Boucheron. (*Electrical Experimenter*, 7, pp. 1028—1029 and 1084—1086, February, 1920.)

A *resumé* of a number of circuits using a three-electrode valve for reception purposes. The circuits considered include simple detection circuits, heterodyne regenerative circuits, combined amplifier and crystal detector, two-stage and multi-stage amplifiers, telegraph and telephone transmission circuits.

807. THE USE OF AUDIONS OR THREE-ELECTRODE LAMPS DURING THE WAR. G. Ferrié. (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 143—148, March, 1920.)

See RADIO REVIEW Abstract No. 424, June, 1920.

808. TECHNIQUE OF DISCHARGE TUBES. F. Schroter. (*Elektrotechnische Zeitschrift*, 40, pp. 685—687, December 25th, 1919. *Revue Générale de l'Électricité*, 7, p. 198D, June 19th, 1920—Abstract.)

This article deals with the use of discharge tubes containing rarefied gas as alternating current rectifiers. Formulæ are given for the current flow through such tubes and some practical forms are illustrated.

809. ELECTRIC CURRENT RECTIFIERS. Siemens Schuckertwerke. (*British Patent* 142465, April 26th, 1920. Convention date, February 7th, 1917. Patent not yet accepted but open to inspection.)

An arrangement of a series of rectifying valves and condensers identical with that described in RADIO REVIEW Abstract No. 117, January, 1920. (See also RADIO REVIEW, 1, p. 264, February, 1920, for correction to the circuit diagram in Abstract No. 117.)

810. DIRECTIONAL WIRELESS RECEPTION. J. Robinson. (*British Patent* 134342, November 4th, 1918. Patent accepted November 4th, 1919.)

In order to avoid missing any parts of a message that may be received at a direction finding station when working the frame aerials (or radiogoniometer) at their minimum position in order to determine the direction of the incoming signal, it is suggested that the same signals should be picked up on a non-directive aerial and combined with that received on the directive aerial, so that in the minimum position of the receiving frame (or radiogoniometer) the signal strength does not fall to zero but is merely reduced to a minimum value. The non-directive aerial may for example consist of a pair of fixed coils at right angles to each other or may be one of a number of other arrangements described in the specification.

811. DIRECTIVE WIRELESS SIGNALLING. C. S. Franklin. (*British Patent* 140538, January 17th, 1919. Patent accepted April 1st, 1920.)

In an arrangement for directional signalling using two aerials spaced a known fraction of a wavelength apart each aerial is provided with its amplifying valve the grid circuit of which is supplied through a tuned circuit from a central control valve which generates the oscillations. The dynamo which supplies the control valve also feeds the amplifying valves for each aerial through a special wire provided for that purpose between the central station and the two aerials. The phase relation of the currents in the two aerials may be controlled by means of the tuned circuits coupling the control valve with the amplifying valves.

812. "ON THE GONIOMETRIC FUNCTIONS APPLICABLE TO DIRECTIVE AERIALS." J. B. Brady; G. W. Pickard; A. Blondel. (*Radio Review*, 1, pp. 256—258, February, 1920.)

Correspondence relative to the paper by A. Blondel with the above title.*

* See RADIO REVIEW, 1, pp. 1—10, October, 1919; pp. 58—66, November, 1919; pp. 110—123, December, 1919.

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813. WIRELESS TELEGRAPHY IN MODERN NAVIGATION. O. Nairz. (*Telefunken Zeitung*, 3, No. 18, pp. 60—62, October, 1919.)
A short description of the use of directional wireless.

814. DIRECTION AND POSITION FINDING. H. J. Round. (*Telegraphen- und Fernsprech-Technik*, 9, p. 34, May, 1920—Abstract.)
See RADIO REVIEW Abstract No. 507, July, 1920.

815. NEW EXPERIMENTS ON SPARK RADIOTELEGRAPHIC DIRECTIVE TRANSMISSION. F. Kiebitz. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 299—310, April, 1920.)
An account of experiments, still in progress, on directive transmission using twin pairs of vertical antennæ similarly excited. In the simple case, if one pair is used the maximum signals are received in the plane containing the two antennæ while the minimum signals are received in a plane at right angles to this, midway between the antennæ. A simple application of such directive transmission is in the controlling and guiding of a distant vessel along a particular course. For such a case the direction of minimum transmission is most defined.

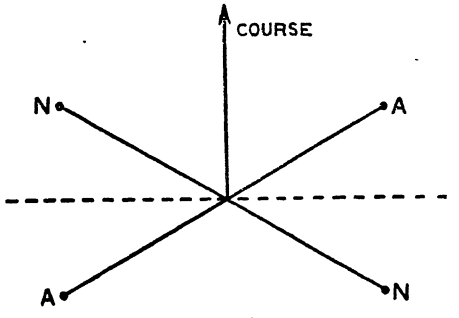

FIG. 6.

Various further applications can be made of this principle if two pairs of antennæ are used. A simple scheme is shown in Fig. 6 in which AA represent one pair of antennæ and NN the other, the angle between AA and NN being small. A convenient scheme is for the two N antennæ to send out the Morse letter "N" and for the A antennæ to send out simultaneously the Morse letter "A." Thus a vessel or flying machine following the course hears both equally well but on deviating from the course hears one stronger.

Experiments with a slight variation of this arrangement (with one antenna AN taking the place of the two A and N on the side of the course) have been carried out to check the utility of the scheme over a known course. It was found that the null point for one pair of antenna sending was about 30 metres broad at a distance of 3½ km. (ten times the wavelength) and the direction about 10 degrees north of the actual theoretical direction. When both antennæ were sending the signals which indicated the course were "12 metres broad" at a distance of 3·5 km. This corresponds to an angle of about 10 minutes.

816. ATMOSPHERIC ELECTRICITY. W. F. G. Swann. (*Journal of the Franklin Institute*, 188, pp. 577—606, November, 1919.)
The author discusses various phenomena of atmospheric electricity and of atmospheric electric measurements including potential gradient, conductivity, etc., and discusses in considerable detail the question of the ionisation of the atmosphere, and experiments which have indicated that above a height of 700 metres from the earth's surface the measured value for the ionisation commences to increase, until at an altitude of 9 km. the average ionisation is from three to four times that at the earth's surface and is increasing very rapidly with increase of altitude. He therefore concludes that this ionisation at high altitudes is not due to radioactive material in the earth's surface but to X-rays or γ rays set up by the impact of negatively charged particles or electrons with the gases of the upper atmosphere. This γ radiation would have very great penetrating and ionising powers. It is further stated that the production of the aurora would also require the impact of electrons or charged particles having a speed sufficiently high for the production of this penetrating radiation.

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817. THE LENGTHS OF PATH OF THE NEWTONIAN LUMINOUS RADIATION AND THE ZONES OF SILENCE IN DAMPED RADIO SIGNALS. G. Sagnac. (*Comptes Rendus*, 170, pp. 800—803, March 29th, 1920. *Revue Scientifique*, 58, p. 222, April 10th, 1920—Abstract. *Bulletin de la Société Belge des Électriciens*, 34, p. 137, July, 1920—Abstract.)

The author refers to some extensive experiments carried out by Admiral H. B. Jackson in 1895 in which zones of silence were observed in the case of radio transmission between three ships in line. From the distance between these zones of silence he deduced that the radial component of the speed of the earth through the ether must be of the order of 400 km. per second and is therefore much greater than the earth's orbital velocity and approaches the observed velocities of the largest stars.

818. RADIOTELEGRAPHY DURING THE SOLAR ECLIPSE OF MAY 29TH. (*Nature*, 104, pp. 323—324, November 20th, 1919. *Science Abstracts*, 23B, pp. 68—69, Abstract No. 139, January, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 24—26, October, 1919. Also RADIO REVIEW Abstracts Nos. 302, April, 1920, and 364, May, 1920.

819. WIRELESS COMMUNICATION BETWEEN HOLLAND AND INDIA. (*Elektrotechnische Zeitschrift*, 41, p. 439, June 3rd, 1920.)

Some particulars are given as to the power and equipment of the installations.*

820. A CONTRIBUTION TO THE STUDY OF SUBMARINE RADIO COMMUNICATION. L. Bouthillon. (*Revue Générale de l'Électricité*, 7, pp. 696—700, May 20th, 1920. *Technical Review*, 6, pp. 588—589, July 6th, 1920—Abstract.)

A brief *resumé* is first given of previous work and of publications dealing with loop and other aerial arrangements for radio communication with submarines,† while the second part of the article is devoted to the theoretical consideration of the attenuation of the electromagnetic wave as it penetrates to various depths into sea water. The amplitude of an electromagnetic field at a depth z in any given medium is given by $I = I_0\epsilon^{-dz}$ where z is the depth and d is a damping coefficient for which the complete expression is given by Zenneck. The author shows that in the case where the material has considerable conductivity, as in the case of sea water, the expression for d becomes $2\sqrt{\omega\sqrt{\pi}\,.\,c_2}$ where ω is $2\pi \times$ the wave frequency, and c_2 is the specific conductivity of the water. Hence the wave amplitude will be reduced in the ratio of $1/\epsilon$ at a depth of 50 cms. for a wavelength of 300 metres, at a depth of 160 cms. for a wavelength of 3,000 metres and at a depth of 500 cms. for a wavelength of 30,000 metres. Curves and tables are also given from which may be ascertained the equivalent distance of transmission over the surface of the sea at which the signal strength will be the same as that obtained at various depths below the surface and at various distances from the transmitter. These curves emphasise the great advantages of long wavelengths for such purposes.

821. THE EVOLUTION OF THE LOW FREQUENCY AMPLIFIER DURING THE WAR. H. Dubosq. (*La T.S.F. Moderne*, 1, pp. 11—18, April, 1920; pp. 41—47, May, 1920.)

This article traces the evolution of the low frequency amplifiers used by the French army. Illustrations are given of the various types together with circuit diagrams of the arrangements.

The second part of this article deals with the amplifiers designated by 2-bis, 3-bis, the famous 3-ter and the No. 4. Connection diagrams are given for each of these arrangements and photographic illustrations of the complete apparatus. A few particulars are also included of the windings used in inter-valve transformers. In the well-known 3-ter type of amplifier three valves are employed the first one of which is provided with a change-over switch so that

* See RADIO REVIEW Abstracts No. 304, April, 1920, and No. 514, July, 1920.

† See for example RADIO REVIEW Abstracts No. 85, December, 1919, and No. 682, August, 1920.

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it may serve either as an ordinary detecting valve with a grid condenser and leak or as a simple low frequency amplifying valve with an iron core input transformer. The remaining two valves are low frequency amplifiers with transformer couplings. The type 4 amplifier differs from the type 3-ter by the addition of a telephone transformer in the output circuit of the last valve. Both these types were arranged for either wireless reception or for earth current signalling.

822. A SEPARATE OSCILLATOR FOR C.W. RECEPTION. (*Wireless World*, 8, pp. 173—174, May 29th, 1920; and pp. 209—212, June 12th, 1920.)

Constructional details are given for a simple inductively coupled separate heterodyne oscillator using a V.24 valve with pancake type inductances in the anode and grid circuits.

823. CRYSTAL DETECTOR. L. Bordat. (*French Patent* 500579, June 10th, 1919. Published March 17th, 1920.)

In a crystal detector apparatus for wireless telegraphy, the characteristic feature is that the parts are jointed so that the crystal carrier and the needle carrier can be arranged in any position in relation to each other.

824. CRYSTAL DETECTOR. V. J. Brochard. (*French Patent* 501156, November 19th, 1918. Published April 6th, 1920.)

For further particulars, see British Patent 139904.*

825. CRYSTAL DETECTORS. V. J. Brochard. (*British Patent* 139904, April 2nd, 1919. Patent accepted March 18th, 1920.)

A special construction for a totally enclosed crystal detector is described in which the whole detector is mounted in an insulating tube filled with a soft insulating material.

826. MOVING IRON RECORDING GALVANOMETERS. H. Abraham and E. Bloch. (*Comptes Rendus*, 169, pp. 171—174, July 28th, 1919.)

The authors describe the construction of moving iron galvanometers which may be adapted for use either as recording oscillographs, relays or mirror oscillographs. The special features are that the moving iron armature is so placed relative to the fixed magnetic field that it is symmetrically magnetised with respect to its axis of rotation. The control is then obtained by means of a spring. The magnetic circuit for the variable currents passing through the windings is closed through the pole pieces and the armature without passing through the body of the permanent magnet. Accidental demagnetisation is thus avoided. A sensitiveness of from 1 to 10 millimetres per milliampere may be obtained.

827. AN AUTOMATIC CALL DEVICE. B. Binyon. (*Wireless World*, 8, pp. 158—167, May 29th, 1920. *Technical Review*, 6, p. 624, July 20th, 1920—Abstract.)

Paper read before the Wireless Society of London—see RADIO REVIEW, 1, pp. 436—437, June, 1920, for abstract. The full report of the discussion is also included with the original paper, which contains illustrations of the complete apparatus and of some of its parts.

828. RADIOTELEGRAPHIC FILTER OR X-STOPPER. (*Revue Générale de l'Électricité*, 6, p. 610, November 1st, 1919. Abstracted from the *Journal of the Franklin Institute*, 187, p. 512, 1919.)

Various forms of apparatus are described for eliminating atmospheric disturbance by acoustic resonance to the group frequency of the incoming signals.

829. THERMIONIC AMPLIFIERS. H. D. Arnold. (*British Patent* 140829, March 27th, 1920. Convention date, September 3rd, 1915. Patent not yet accepted but open to inspection.)

The arrangement described is designed to act as a limiter for incoming impulses so that the strength of disturbances is reduced to a value not exceeding that of the signals. As distinct from the ordinary arrangements the incoming impulses are first amplified so that as far as

* RADIO REVIEW Abstract No. 825.

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possible uniform amplification is obtained irrespective of the voltage of the impulse. In Fig. 7 the valve V_1 acts simply as an amplifying valve and its output circuit including the coils L_1 and L_2 is provided with a reaction coupling L_2 back to the grid circuit L so as to exactly neutralise the natural coupling through the grid-plate capacity of the valve. V_2 is the detecting valve and the output from this valve is passed to the two low frequency amplifying valves

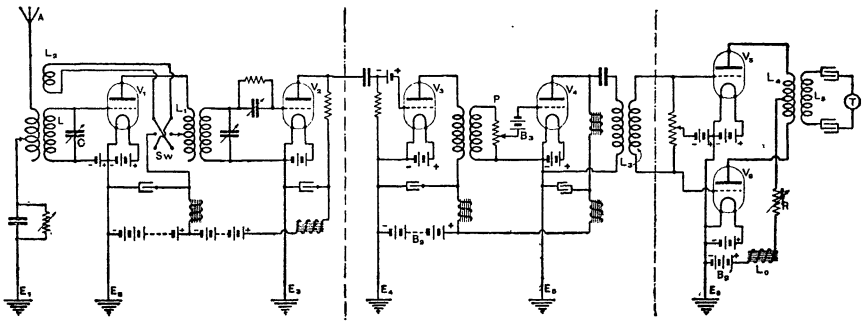

FIG. 7.

V_3 V_4 which are inductively coupled as shown, the amount of amplification being controlled by the potentiometer P. The limiting effect takes place in the last stage which includes the two valves V_5 V_6 connected in opposition in the circuit L_3 L_4. The choke coil L_0 serves to maintain as constant as possible the output from the battery B_2 while the resistance R also tends to limit the plate currents of these valves V_5 V_6. The receiving instrument T is coupled through the differential transformer L_4 L_5 to this last amplification stage. The limiting action is secured by adjustment of the voltage of B_2 so that the normal current that can pass through V_5 V_6 is only just greater than the amplitude of the signals to be received. The receipt of a more powerful impulse will then cause the plate current of one valve to be reduced to zero while the other one cannot be increased to more than its saturation value so that the signal strength in T cannot increase beyond the ordinary signal strength.*

830. THERMIONIC AMPLIFIERS. H. D. Arnold. (*British Patent* 141033, March 24th, 1920. Convention date, March 28th, 1919. Patent not yet accepted but open to inspection.)

This specification provides for an arrangement of a multi-stage triode amplifier so that the ratio of amplification may be varied without varying the impedance offered by the amplifier as a whole to the impulse to be amplified. The arrangement described is identical with that enclosed between the dotted lines in the centre of Fig. 7 above. The ratio of amplification may be varied by means of the potentiometer resistance P (of about 500,000 ohms) which is connected between the output of the first valve V_3 and the input of the second valve V_4. The battery B_3 serves to maintain the grid of V_4 at a negative potential so that the valve offers a substantially infinite impedance to incoming impulses. The two valves may be supplied from the common H.T. battery B_2 through the choking inductance shown.

831. SOME OF THE PROBLEMS OF ATMOSPHERIC ELIMINATION IN WIRELESS RECEPTION. P. R. Coursey. (*Wireless World*, 8, pp. 191—201, June 12th, 1920; and pp. 225—234, June 26th, 1920. *Technical Review*, 6, p. 659, August 3rd, 1920—Abstract.)

Paper read before the Wireless Society of London, together with verbatim report of the discussion—see RADIO REVIEW, 1, p. 492, July, 1920, for abstract.

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* See also RADIO REVIEW Abstract No. 8.

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832. THE USE OF GROUND WIRES AT REMOTE CONTROL STATIONS. A. H. Taylor and H. Crossley. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 171—192, January, 1920.)

The investigations of A. H. Taylor * have shown that a subterranean receiving system possesses many important advantages, *e.g.*, high degree of directivity and immunity from atmospherics. By utilising this directional selectivity it has been found possible to install receiving stations in the immediate vicinity of transmitting systems. The installation of such "remote" control stations at Great Lakes, Norfolk and New Orleans is described. The first station may be taken as typical. At this station there are two transmitting antennæ, the lower for spark working (600 to 1,500 metres) and the upper for spark (1,500 to 3,400 metres) and arc (3,000 to 10,000 metres) working. The subterranean receiving station was built only 600 feet from the nearest tower of the transmitting station. The actual receiving tent was carefully covered with wire screening. A very small crack in the door of the screen cage would admit sufficient energy from the neighbouring transmitter to interfere with the reception of distant signals. The actual ground wires were laid as nearly as possible at right angles to the direction of the transmitter. There was however some small deviation from this right-angled relationship so that signals especially on certain wavelengths penetrated to the receiver. It was found possible to eliminate this by using a very small loop in series with one of the ground wires and placed outside the receiving tent. The loop could be rotated until minimum interference was obtained. The use of the loop was only necessary when transmitting and receiving on identical wavelengths.

It was found that the electrical impulses which the ground wires pick up are not nearly as strong as might be expected from the close proximity of the transmitter. This is attributed to the fact that the waves must travel some distance before they obtain the necessary forward slant which makes ground wire reception possible.

A detailed description of the design and lay-out (including telephone connections between transmitting and receiving stations) of the Great Lakes station is given.

In the discussion J. Mills emphasised the necessity for the quantitative comparison of receiving stations with reference to their efficiency in reducing the effects of strays and interfering signals. A rough outline of such a method was also given.

833. FRAME AERIALS. A. Esau. (*Telefunken Zeitung*, 3, No. 18, pp. 51—59, October, 1919.)

A description of many forms of frame aerials, small portable ones, collapsible ones, and large ones supported on masts; their advantages and special characteristics are discussed.

834. AERIALS: DUPLEX SIGNALLING. H. J. J. M. de R. de Bellescize. (*French Patent* 501428, November 7th, 1918. Published April 14th, 1920.)

This specification describes a system of duplex wireless telegraphy. For further particulars, see British Patent 136524.†

835. AERIALS FOR WIRELESS SIGNALLING. J. H. Rogers. (*British Patent* 137511, November 20th, 1919. Convention date, January 10th, 1919. Patent accepted March 11th, 1920.)

An arrangement of aerial is described as being suitable for use on a submarine. Two wires are stretched out longitudinally above the vessel one running forward and the other aft, and are led in through insulators in the conning tower. The ends of the wires are connected to the hull of the vessel at each end, and a tuning condenser is inserted between the adjacent ends of the wires inside the vessel so as to form a loop aerial which may be connected to the transmitting and receiving apparatus in the usual manner.‡

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* See RADIO REVIEW Abstracts No. 149, January, 1920, and No. 313, April, 1920.

† RADIO REVIEW Abstract No. 493, July, 1920.

‡ See also RADIO REVIEW Abstract No. 85, December, 1919.

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836. ELECTRICAL ENGINEERING IN 1919—WIRELESS TELEGRAPHY AND TELEPHONY. (*Engineer*, 129, p. 9, January 2nd, 1920.)

A very brief *resumé* of the chief lines of radio progress during 1919.

837. THE ROME RADIO STATION OF THE ITALIAN NAVY. C. F. Elwell. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 193—198, June, 1920.)

Describes in detail the arc station at Rome built rapidly during the war to cope with traffic from Italy to America and to the Italian colonies in Africa.

The following is a brief summary of the details :—Range of station 4,200 miles ; antenna of triangular type 714 feet high ; antenna capacity 0·011 mfd. ; arc generator rated at 200 kW. (250 amperes at 800 volts).

838. THE GERMAN IMPERIAL WIRELESS NETWORK. (*Telefunken Zeitung*, 4, No. 20, pp. 15—16, May, 1920. Also *Electrician*, 83, p. 114, July 23rd, 1920—Abstract.)

Particulars are given of the German network of radio stations with a map showing those in use and those under construction.

839. THE INTERNAL AND INTERNATIONAL ORGANISATION AND DEVELOPMENT OF GERMAN WIRELESS IN SHIPPING. F. H. Quiring. (*Telefunken Zeitung*, 4, No. 20, pp. 23—34, May, 1920.)

An abstract from a thesis for the doctor degree.

840. THE RADIOTELEGRAPHIC STATION AT ROME (SAN PAOLO). B. Micchiardi, G. Pession, and G. Vallauri. (*L'Elettrotecnica*, 7, pp. 218—224, May 5th, 1920, and pp. 241—244, May 15th, 1920 ; and also Editorial Notes on pp. 217 and 237. Also *Electrical World*, 75, p. 1207, May 22nd, 1920—Abstract.)

See Abstract No. 538, July, 1920, where a translation of this article has already been abstracted.

841. THE WIRELESS STATION AT WARSAW. (*La T.S.F. Moderne*, 1, pp. 7—11, April, 1920.)

A short illustrated description giving details of the 12 kW. Telefunken station captured from the Germans by the Polish Army.

842. FRENCH RADIO STATION TO HAVE 13,000-MILE RANGE. (*Electrical Experimenter*, 7, p. 110, March, 1920.)

A few brief notes relative to the Bordeaux station. 500 kW. is to be provided in the antenna and the station is to be capable of sending 72,000 words per day.

843. VALVE RADIOTELEGRAPHIC STATIONS. C. Gutton. (*La T.S.F. Moderne*, 1, pp. 32—40, May, 1920.)

This article deals with the arrangement of simple valve transmitting and receiving stations. For transmitting two valves are employed connected in parallel with an ordinary arrangement of inductive reaction coupling. For receiving a three-valve arrangement is described with inductive coupling to the aerial circuit, the first valve acting as detector and the other two as low frequency amplifiers. The complete connection scheme for the whole station is given and simple methods of adjusting the apparatus for wavelength, power, etc., are also dealt with. The station described is similar to arrangements developed in the French military radiotelegraphic laboratories.

844. INDUCTANCES. R. F. Gowen. (*British Patent* 141344, April 1st, 1920. Convention date, April 4th, 1919. Patent not yet accepted but open to inspection.)

This specification covers the construction of inductances with spaced windings similar to the so-called "honeycomb" pattern of coil. This construction reduces the self capacity of the winding.

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845. THE CONSTRUCTION OF HONEYCOMB INDUCTANCES. H. R. Moore. (*Electrical Experimenter*, 7, p. 1160, March, 1920.)
The construction of a simple machine for winding these coils is described.

846. NAUEN. E. Quack. (*Telefunken Zeitung*, 3, No. 17, pp. 20—26, August, 1919.)
A general illustrated description of the rise and development of Nauen Wireless Station.

847. NAUEN DURING THE WAR. B. Schuchardt. (*Telefunken Zeitung*, 3, No. 17, pp. 27—29, August, 1919.)
A popular account of the development of Nauen during the war.

848. THE NAUEN TOWERS. F. Brückerbohm. (*Telefunken Zeitung*, 3, No. 17, pp. 51—60, August, 1919.)
A well-illustrated descriptive article.

849. THE ERECTION OF THE NEW BUILDINGS OF THE NAUEN STATION DURING THE WAR. H. Rabes. (*Telefunken Zeitung*, 3, No. 17, pp. 46—50, August, 1919.)
A well-illustrated descriptive article.

850. VARIABLE INDUCTANCE. H. P. Donle. (*U.S. Patent* 1332453, December 15th, 1917. Patent granted March 2nd, 1920.)
The arrangement described provides for the means of moving two coils relative to one another so as to vary their mutual inductance, and a switch to automatically change the connections so that the windings assist or oppose one another in order to obtain a continuous range of variation of the inductance of the whole.

851. THE DISTANT CONTROL OF ELECTRICAL APPARATUS. Chauveau. (*Bulletin Officiel de la Direction des Recherches et Inventions*, No. 3, pp. 179—186, January, 1920. *Revue Générale de l'Électricité*, 7, p. 156D, May 15th, 1920—Abstract.)
An electrical apparatus suitable for control either by wire or wireless is described.

852. THE EFFECT OF RAREFIED ATMOSPHERE ON SPARK TRANSMITTERS. F. Jentzch-Graefe. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 311—317, April, 1920.)
Numerous reports from the German front have indicated that frequently radio-transmission was not possible with the earth from heights of over 6,000 metres. The problem thus presented has been investigated by laboratory methods using a German D type transmitter. The influence of an extremely low temperature was studied by maintaining the temperature of the transmitter and complete valve receiver at $-40°$ C. The wavelength and decrement of the transmitter were unaltered and only small variations were noted in the amplifier battery voltage. The influence of the reduction in pressure was next studied, the spark gap being enclosed in a chamber from which the air could be pumped. The relation between antenna current and pressure was determined. It was found that the antenna current very gradually diminished until the pressure was 360 mm. below normal, but that between this pressure and 430 mm. below normal the current dropped rapidly (*e.g.*, in one case from 0·62 amps. to 0·1 amps.). For pressures lower than this the antenna current remained extremely small resulting of course in weak radiation. The pressures mentioned, 360 mm. to 430 mm. below normal, correspond to heights of 5,500 metres to 6,500 metres.

853. IS WIRELESS TELEGRAPHY SUITABLE AS A MEANS OF COMMUNICATION IN LARGE ELECTRIC POWER DISTRIBUTION SYSTEMS? G. Schmidt. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 16—17, April, 1920.)
A discussion of the advantages and disadvantages of wireless as compared with ordinary

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line telephony. He finally recommends the use of the overhead power lines as guides for what would otherwise be a wireless telephone system.

854. MULTIPLEX TELEPHONY AND TELEGRAPHY WITH OPEN-CIRCUIT BARE WIRES. G. O. Squier. (*Journal of the Franklin Institute*, 189, pp. 693—714, June, 1920. *Electrician*, 84, pp. 641—643, June 11th, 1920—Abstract. *Times Engineering Supplement*, No. 547, p. 173, May, 1920—Abstract. *Electrical Review*, 86, p. 592, May 7th; pp. 710—711, June 4th, 1920—Abstract. *Electrical World*, 75, p. 1020, May 1st, 1920—Abstract. *Telegraph and Telephone Age*, 38, pp. 384—390, July 16th, 1920, and pp. 417—420, August 1st, 1920—Abstract. *Wireless Age*, 7, pp. 20—21, July, 1920—Abstract.)

Refers to the use of high frequency alternating current for communication along bare wires laid in sea water. Frequencies of 600,000 and 1,000,000 have been used in experiments with transmitting currents up to 270 milliamps.

For reception a triode detector and amplifier was used as a potentially operated receiver, leaving the usual earth connection open.

The article also refers to a new type of radiogoniometer for determining absolute directions in which use is made of a long helix on which stationary waves are set up. One end of the helix is earthed and the point of highest potential connected to the grid of the triode detector.

855. INTERPLANETARY WIRELESS. Q. Majorara. (*L'Elettrotecnica*, 7, pp. 198—200, April 25th, 1920.)

A discussion of the possibility of signals from Mars or other planets.

856. INTERPLANETARY COMMUNICATION. C. S. Brainin. (*Electrical Experimenter*, 7, p. 641, November, 1919.)

Discussion of the possibilities of communication with other planets.

857. RADIO FREQUENCY CURRENTS ON WIRES. J. O. Mauborgne. (*Electrical Experimenter*, 7, p. 1156, March, 1920.)

See RADIO REVIEW Abstracts No. 565, July, 1920, and No. 175, January, 1920, for abstract of articles covering the same subject-matter. This particular account includes an illustration of the apparatus used in the first "wired-wireless" tests in Canada in May, 1919, between Toronto and Hamilton over a distance of forty to forty-five miles.

858. AMPLIFYING APPARATUS. Société le Matériel Téléphonique. (*French Patent* 500654, June 12th, 1919. Published March 20th, 1920.)

The invention relates to apparatus for signalling at high frequency. For further particulars, see British Patent 130432.*

2. Books.

LEÇONS DE PHYSIQUE GÉNÉRALE. By J. Chappuis and A. Berget. Vol. II. Électricité et Magnétisme. Revised by J. Chappuis and M. Lamotte. (Paris: *Gauthier Villars et Cie.* Third Edition, 1920. Pp. 623. Price 45 fr.)

This third edition of the well-known text-book of physics has been completely revised and rewritten by Chappuis and Lamotte. It is intended to cover the course followed at the École Centrale des Arts et Manufactures by

* RADIO REVIEW Abstract No. 294, April, 1920.

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the candidates for the Licence ès Science Physique. It presupposes more than an elementary knowledge of mathematics as the first section deals with potential theory and introduces partial differentials, direction cosines, Poisson's equation, etc. On the descriptive and experimental side, however, it presupposes very little, if any, previous knowledge. It deals not only with pure physics but with such applications as polyphase currents and star and mesh connection, although, of course, such things are not considered at any length. There is a chapter on industrial electrical measuring instruments.

G. W. O. H.

WIRELESS TELEGRAPHY AND TELEPHONY: First Principles, Present Practice and Testing. By H. M. Dowsett, M.I.E.E. (London: *The Wireless Press, Ltd.* 1920. Pp. xxxi. + 331. Price 9*s.* net.)

One feature of this book which might with advantage be copied in many others is the table of symbols on p. 1 which are to be used in the interpretation of the drawings. It would be a good thing if some international agreement could be reached on this subject, as it would save both time and trouble for those who have to deal with the voluminous literature which is now available in wireless telegraphy. The book opens, as a good many other books on this subject do nowadays, with a chapter on the nature of electricity and the atom. It is a good thing that the electrician of to-day should be more fully acquainted than his predecessors were with the nature of the forces with which he is dealing, but one is inclined to doubt whether any great advantage is to be gained by the person for whom this book is intended by a study of the very ingenious models which the author has devised, showing atomic structure. They are hardly consistent with the structure that distinguished physicists like Rutherford and Bohr have postulated, and though one does not wish to claim a monopoly of physical knowledge for the professional physicists, it would perhaps have been better if speculations so doubtful in their validity as to the form and structure of the atom had been omitted. The same criticism applies to the highly problematical structure of the ether during the process of the generation of the magnetic field. On the other hand, the very praiseworthy efforts made later in the book to give some physical conception of what really happens when electro-magnetic waves are "whipped off" a radiator, is deserving of commendation. Very little has been written on this subject since Hertz's original experiments, and the suggestion of the electrons carrying the ends of lines of electric force as they oscillate backwards and forwards on a radiator, and of the lines of force automatically, as it were, becoming detached from the oscillator when their ends cross gives a valuable mental picture which should help the student to understand what is really happening when an oscillator is producing a train of electric waves. One criticism should be made here which it is hoped will lead to correction. All the vector diagrams are shown with the vectors rotating clockwise. It has now been agreed by the International Electro-Technical Commission that the standard direction of rotation should be counter-clockwise.

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The chapter on the spark discharge is very good. The methods of adjusting the Marconi spark discharger and the theoretical discussion of its working are of great interest and should be most valuable to those who are using this type of apparatus. There is also a description of the quenched spark system used by the Marconi Company, and the principles of this also are discussed. There is a most valuable description in the next chapter of the various forms of continuous wave transmitter. Not only are the well-known alternators devised by Alexanderson and Goldschmidt described, but the high frequency generator used by the French radio engineers is explained, as well as the various types of static transformer frequency changers which have been in use at the German continuous wave stations at Nauen and elsewhere. The Marconi timed spark system which has been employed so successfully at Carnarvon is explained, and a full account given of the 25 kW. Marconi-Poulsen arc generator with all its improvements.

The following chapter (V.) deals with thermionic valves; it is somewhat marred by a very imaginative account of the movement of secondary electrons in atoms which are interchanging electrons. The description, however, of the various types of valves and valve circuits is excellent. The arrangement of valve circuits to give retroaction, amplification and heterodyning is exceedingly full and clear, and to any one interested in the practical use of valves (and that nowadays includes every radio engineer), the descriptions will be of the greatest possible assistance. At the end of the chapter an account is given of valve telephone circuits and of some of the methods used in wireless telephony. The great merit of this part of the book is that it is so evidently the work of one who has had the practical handling of the apparatus, and who, at the same time, understands the principle of action of the gear with which he has to deal. There is a short account of high speed telegraph apparatus (including the Einthoven galvanometer) used for automatic recording.

In the next few chapters a short account is given of the methods of measuring current, potential difference and resistance. In the chapter dealing with measurement of capacity, there is a very good description of the methods of finding accurately at high frequency the value of the capacity of the small condensers with which the wireless engineer has usually to deal; an equally useful chapter describes the methods of measuring inductance. The chapter on measurement of frequency is one of the best in the book. Not only are the better known methods of measuring low frequencies described, but the determination of high frequencies by photography of the spark and the method of spark counting by dictaphone are explained. The arrangement of the Lecher wire system for calibrating wavemeters and other methods of wavemeter calibration are mentioned. A very good account of the determination of dielectric strength is given in Chapter XII. including the arrangement of spherical electrodes used by the National Physical Laboratory and its limitations, and a useful table of sparking voltages between needle points and balls is included. The methods used for testing insulators and bushings are also explained. The measurement of decrement forms the subject of the next chapter, which is also very full and

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complete, and in this is contained an account of the determination of the decrement due to the resistance of the spark. The fact that the decrement in a spark circuit is not constant but increases as the spark dies away is here stated; a fact of great importance. Very few measurements of spark resistance have been published, and the subject is one that deserves further study. The measurement of the decrement of coupled circuits and of the Marconi decremeter are described, the chapter concluding with an account of the determination of the decrement of antennæ, due to radiation, brushing, dielectric hysteresis, eddy currents, ohmic resistance and earth resistance. The last chapter deals with direction finding and the measurement of signal strength. This book is one which will prove of great value to every practical radio engineer, it is the work of an expert in the operation of wireless apparatus, and is full of information which hitherto has not been available in so compact and convenient a form.

E. W. MARCHANT.

THE PRACTICAL ENGINEER'S ELECTRICAL POCKET BOOK AND DIARY FOR 1920. (London: *The Technical Publishing Co., Ltd.* Pp. clxiv. + 592 + 56 (Diary). Price 1*s.* 6*d.* net; best cloth binding 2*s.* net.)

This pocket book contains the usual collection of mathematical and electrical tables with explanatory notes arranged for handy reference, and also a number of sections each devoted to a particular branch of electrical work. These sections on the whole contain a quantity of handy and valuable information, but amongst them is one entitled "Wireless Telegraphy," in which a very brief *résumé* is given of the action of a transmitter using the spark system. The only diagram given, however, is that of an obsolescent arrangement using a magnetic detector, while more modern apparatus is hardly mentioned. A statement is also noticed to the effect that a valve detector is connected *in series* with the oscillatory circuit. Some reference to more modern wireless books than those quoted would be useful in this section. A diary and Buyers' Dictionary in three languages concludes the book.

P. R. C.

Books Received.

INTRODUCTION À LA THÉORIE DES COURANTS TÉLÉPHONIQUES ET DE LA RADIO-TÉLÉGRAPHIE. By J. B. Pomey with a Preface by A. Blondel. (Paris: *Gauthier-Villars et Cie.*, 1920. Pp. xiv + 510. Price 50 frs.)

WORKING DIAGRAMS OF VALVE AMPLIFYING RECEIVER CIRCUITS. By H. W. Sullivan. (London: *H. W. Sullivan*, 1920. Pp. 24. Price 1s.)

A New Dutch Radio Society.

The Nederlandsch Radio Genootschap was founded on May 29th, at Amsterdam, under the direction of Professor G. J. Elias as chairman, and Dr. Balth van der Pol as vice-chairman. The Society aims to be the centre of scientific radio work in Holland. The address of the Society's offices is W. Barentzstraat, 8, Utrecht, the secretary being Ir. H. Nordlohne.

Messrs. Vickers, Ltd., Broadway, London, S.W. 1, inform us that they have opened a depôt for Wales and the south-west of England at 43, Park Street, Bristol, at which address they will be glad to receive enquiries for their products.

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THE
RADIO REVIEW

VOL. I OCTOBER, 1920 NO. 13

Regeneration and Oscillation in Vacuum Tube Circuits through Inter-Electrode Tube Capacity.*

By A. S. BLATTERMAN
(Radio Engineer, Signal Corps, U.S. Army).

Early in 1918 the writer suggested the importance of knowledge (then lacking) of the effective impedance between the input electrodes of the three electrode vacuum tube in radio circuits, and preliminary measurements made at these laboratories† showed that the nature and value of this impedance was materially influenced by the load in the plate or output circuit of the tube. Because of the urgency of other work at that time the problem was outlined to the National Bureau of Standards Radio Laboratory and assigned to them by the Signal Corps for investigation. Dr. Miller's paper entitled "The Dependance of the Input Impedance of a Three Electrode Vacuum Tube upon the Load in the Plate Circuit,"‡ covered the results of this investigation and was the first published demonstration of the exact nature and magnitude of the effects taking place within the tube circuits. Since this paper has appeared other authors, notably Nichols§ and Ballantine,‖ have treated the same subject and the importance of the inter-electrodic capacities of the vacuum tube and of the load in its plate circuit when used for reception has been well formulated.

It is the purpose of the present paper to present the matter in a more direct and simple way than has heretofore been done, showing the effects of the different types of loads in the plate circuit of a tube and the conditions necessary for regenerative action and self-oscillation. It will also be shown

* Received July 3rd, 1920.

† Measurements made by Lieutenant M. C. Batsel and Lieutenant Austin Bailey.

‡ *Bureau of Standards Scientific Paper* No. 351, November 21st, 1919. RADIO REVIEW, Abstract No. 416, June, 1920.

§ H. W. Nichols, "The Audion as a Circuit Element" (*Physical Review*, 13, p. 404, 1919). See also RADIO REVIEW Abstract No. 928 (in this issue).

‖ S. Ballantine, "On the Input Impedance of the Thermionic Amplifier" (*Physical Review*, 15, pp. 409—420, May, 1920). RADIO REVIEW Abstract No. 925 (in this issue).

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that the impedance of the input or supply circuit wherefrom the grid receives its excitation is of great importance, a circumstance not pointed out previously.

It is now well known that an electromotive force E_g acting between the grid and filament of a three electrode tube causes a current to flow in the plate circuit thereof whose phase with reference to E_g depends upon the characteristics of the plate circuit impedance. If this latter is purely resistive the plate current and grid voltage are in phase; if inductive, the current lags; and for capacitive loading the plate current leads the grid voltage. It is also well known that the grid voltage E_g can be exactly replaced, as far as effects in the plate circuit are concerned, by a voltage μ times as great acting within the tube between the plate and filament electrodes. The tube has essentially three capacities within its structure, that between its grid and filament, that between grid and plate, and that between filament and plate. We have to consider these capacities with reference to the operating voltages, namely E_g and the fictitious voltage μE_g, and may thus combine the grid-

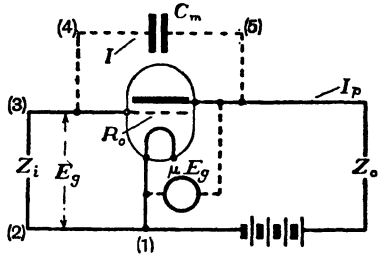

FIG. 1.

filament capacity with the impedance of the input circuit Z_i, and the plate-filament capacity with the impedance of the load or output circuit Z_o (see Fig. 1). The capacity C_m between grid and plate thus becomes the only one which is unique. It has common connection between the input or grid side of the tube and the output or plate side, and any reaction of the output on the input must take place through it. The particular matter which it is desired to investigate is the effect of the impedance Z_i and Z_o upon regeneration effects or oscillation of the circuits.

Regardless of the circuital arrangement of Z_o, be it a single simple reaction unit or a complex network, it can be always resolved into an equivalent impedance comprising series resistance R_p and reactance X_p, and in general therefore it is only necessary to consider the load as so constituted. We have at once, in vector notation, the plate current as

$$I_p = \frac{\mu E_g}{(R_0 + R_p) + jX_p} \quad \ldots\ldots\ldots \quad (1)$$

in which μE_g is assumed as the reference vector. R_0 is the tube resistance between plate and filament, as usual.

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This current develops a reaction voltage across Z_o equal to

$$E_Z' = -(R_p + jX_p)I_p$$
$$= -\mu E_g \frac{R_p + jX_p}{(R_0 + R_p) + jX_p} \quad \ldots\ldots \quad (2)$$

which is impressed on circuit 1, 2, 3, 4 and 5 at points (1) and (5). In practical cases the input circuit of impedance Z_i, like the output circuit impedance Z_o may be constituted in any one of several different forms. It may be generically a high resistance, a large inductance or a capacity, as in resistance, inductance or capacity coupled amplifiers, or it may comprise an equivalent series combination or resistance and reactance. In general, it must be considered as an impedance $(R_g + jX_g)$.

The voltage E_Z' therefore experiences an impedance comprising capacity C_m and the supply circuit $(R_g + jX_g)$ in series. Thus the current produced by E_Z' is

$$I = \frac{E_Z'}{R_g + j(X_g - 1/\omega C_m)}$$
$$= -\mu E_g \frac{R_p + jX_p}{[(R_0 + R_p) + jX_p][R_g + j(X_g - 1/\omega C_m]} \quad \ldots\ldots \quad (3)$$

We see at once that this current develops a voltage across the input impedance Z_i, and the voltage so developed, appearing as it does between the grid and filament electrodes, combines with the original input voltage E_g either favourably for regeneration and oscillation or in opposition when the action is a counter feedback. The impedance Z_i of the supply circuit, since it gives rise to the feedback voltage, is of fundamental importance therefore. The equation for this voltage is obviously

$$E_g' = I(R_g + jX_g)$$
$$= -\mu E_g \frac{(R_p + jX_p)(R_g + jX_g)}{[(R_0 + R_p) + jX_p][R_g + j(X_g - 1/\omega C_m)]} \quad \ldots\ldots \quad (4)$$
$$= -\mu E_g \frac{(a + jb)(c + jd)}{(e + jb)(c + jf)}$$
$$= -\mu E_g \left\{ \frac{(-ac^2e + abcf + bcde - b^2df - b^2c^2 - bcef - abcd - adef)}{(ec + bf)^2 + (bc + ef)^2} - j \frac{(bc^2e - b^2cf + acde - abdf - abc^2 - acef + b^2cd + bdef)}{(ec + bf)^2 + (bc + ef)^2} \right\} \quad (5)$$

wherein

$$a = R_p \qquad d = X_g$$
$$b = X_p \qquad e = R_0 + R_p$$
$$c = R_g \qquad f = X_g - 1/\omega C_m$$

This expression (5) comprises a real and an imaginary term. The imaginary term denotes a voltage acting in time quadrature to the input voltage E_g since this, or rather μ times it, was taken as our reference vector. The real term denotes a voltage either in phase or in exact opposition to E_g depending upon whether its sign is positive or negative. The action is

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counter feedback if the real part of (5) is negative. It is regenerative and favourable for the production of oscillations if the real term is positive. We have at once, therefore, the condition for regenerative action in the general case as

$$abcf + bcde > aec^2 + b^2df + b^2c^2 + bcef + abcd + adef \quad . \quad . \quad (6)$$

Any situation wherein the conditions do not satisfy this relation will either result in the absorption of energy or be critical between absorbing and regenerating action.

There are nine regenerate cases of importance as arising in the design of receiving and amplifying circuits, wherein control of the regenerative feature is desirable and knowledge of the regenerative conditions important. These different cases correspond to arrangements where the supply circuit impedance Z_i is essentially either resistive, inductive or capacitive, and the output impedance Z_o is also either a resistance, an inductance or a capacity.

Case 1.—Z_i = Resistance. Z_o = Resistance. See Fig. 2.

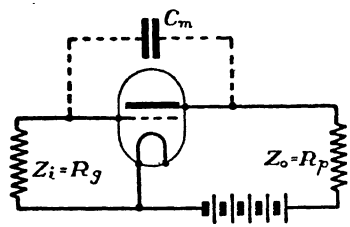

FIG. 2 (*a*).

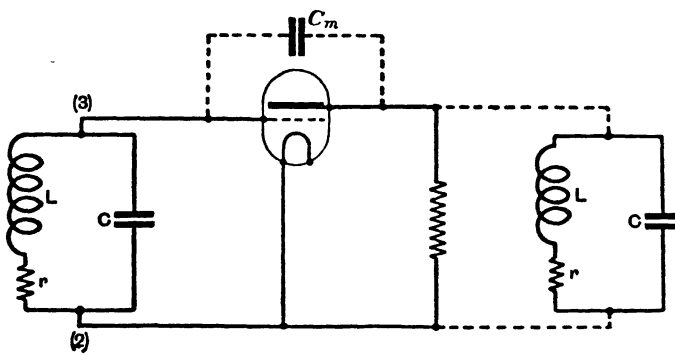

FIG. 2 (*b*).

This corresponds to the case of the resistance coupled amplifier, Fig. 2 (*a*), or to arrangements using tuned circuit input or output as in Fig. 2 (*b*).

In the latter arrangement under this case it is assumed that the adjustments of the circuits *LrC* are for resonance or isochronism or close to these so that the impedance between such points as (2) and (3) is virtually resistive.

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It is desirable to point out here that when such a circuit is tuned so that $\omega L = 1/\omega C$ the impedance of the parallel combination is not purely resistive, but comprises an effective resistance,

$$R_e = \frac{1}{\omega^2 C^2 r} = \frac{L}{Cr} \quad \ldots\ldots\ldots\ldots (7)$$

in series with an effective capacity reactance.

$$X_e = -1/\omega C \quad \ldots\ldots\ldots\ldots (8)$$

The combination becomes the equivalent of pure resistance at a frequency slightly greater than that producing resonance, namely when

$$\omega = \sqrt{\frac{1}{LC} + \frac{r^2}{L^2}} \quad \ldots\ldots\ldots\ldots (9)$$

and it is then

$$\left.\begin{aligned} R_e &= \frac{rL^2}{\omega^2 C^2 L^2 r^2 + r^4 C^2} \\ X_e &= 0 \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (10)$$

The isochronous frequency of the circuit is still different from either of the above frequencies and is given by

$$\omega = \sqrt{\frac{1}{LC} - \frac{r^2}{4L^2}} \quad \ldots\ldots\ldots\ldots (11)$$

The circuit is again the equivalent of a resistance and reactance in series whose values are readily calculable but approximate those of (7) and (8). A few calculations will show at once that for most practical circuits the reactance component in either the tuned or the isochronous adjustment is small compared with the effective resistance, and in all cases to be here considered the impedance can be sufficiently well represented by a resistance of value

$$R_e = \frac{1}{\omega^2 C^2 r} = \frac{L}{Cr} \quad \ldots\ldots\ldots\ldots (12)$$

In the inequality (6) we have to put for Z_i = resistance, Z_o = resistance

$$b = 0 \qquad d = 0 \qquad f = -1/\omega C_m$$

and get

$$0 > R_p R_g^2 (R_0 + R_p)$$

This is an impossibility, and we see, therefore, that *no feedback is possible with plain resistance in input and output.*

Case 2.—Z_i = Resistance. Z_o = Inductance.

For this condition $a = 0$, $b = \omega L_\rho$, $d = 0$, $e = R_0$, $f = -1/\omega C_m$ and (6) becomes

$$\omega^2 L_p C_m R_g < R_0 \quad \ldots\ldots\ldots\ldots (13)$$

This indicates *that regenerative action may be secured in a circuit having a resistance input and inductive load on the plate and specifies the conditions when such action occurs.*

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Case 3.—Z_i = Resistance. Z_o = Capacity.

For this condition $a = 0$, $b = -1/\omega C_p$, $d = 0$, $e = R_0$, $f = -1/\omega C_m$ and (6) becomes

$$0 > \frac{R_g^2}{\omega^2 C_p^2} + \frac{R_g R_0}{\omega^2 C_p C_m}$$

an impossibility, showing *no regeneration with capacity load and resistance input.*

Case 4.—Z_i = Inductance. Z_o = Resistance.

$b = 0$, $c = 0$, $d = \omega L_g$, $e = R_0 + R_p$, $f = \omega L_g - 1/\omega C_m$

(6) becomes

$$\omega^2 L_g R_0 C_m + R_p \omega^2 L_g C_m < R_p + R_0$$

$$\omega^2 L_g C_m < 1 \quad \ldots\ldots\ldots \quad (14)$$

Regeneration is possible and occurs when this condition (14) *is satisfied.*

Case 5.—Z_i = Inductance. Z_o = Inductance.

$a = 0$, $b = \omega L_p$, $c = 0$, $d = \omega L_g$, $e = R_0$, $f = \omega L_g - 1/\omega C_m$

(6) becomes

$$\omega^2 L_g C_m < 1 \ldots\ldots\ldots\ldots \quad (15)$$

as the condition under which regeneration occurs.

Case 6.—Z_i = Inductance. Z_o = Capacity.

$a = 0$, $b = -1/\omega C_p$, $c = 0$, $d = \omega L_g$, $e = R_0$, $f = \omega L_g - 1/\omega C_m$

(6) becomes

$$\omega^2 L_g C_m < 1 \ldots\ldots\ldots\ldots \quad (16)$$

Oscillations are therefore possible in this case and under the same conditions as (14) *and* (15). The form of the inequalities (14), (15) and (16) indicates that the reactance of the grid-plate capacity C_m must exceed that of the input grid inductance L_g.

Case 7.—Z_i = Capacity. Z_o = Resistance.

$a = R_p$, $b = 0$, $c = 0$, $d = -1/\omega C_g$, $e = R_0 + R_p$, $f = -\frac{1}{\omega C_g} - \frac{1}{\omega C_m}$

(6) becomes

$$0 > \frac{R_p}{\omega C_g}\left(R_0 + R_p\right)\left(\frac{1}{\omega C_g} + \frac{1}{\omega C_m}\right)$$

This is an impossible condition, and *no regenerative feedback can therefore occur when the input impedance is capacity and the load resistive.*

Case 8.—Z_i = Capacity. Z_o = Inductance.

$a = 0$, $b = \omega L_p$, $c = 0$, $d = -1/\omega C_g$, $e = R_0$, $f = -\frac{1}{\omega C_g} - \frac{1}{\omega C_m}$

(6) becomes

$$0 > \frac{\omega^2 L_p^2}{\omega C_g}\left(\frac{1}{\omega C_g} + \frac{1}{\omega C_m}\right)$$

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which is obviously impossible so that *no regeneration is possible with capacitive input and inductive load.*

Case 9.—Z_i = Capacity. Z_o = Capacity.

$$a = 0, \quad b = -\frac{1}{\omega C_p}, \quad c = 0, \quad d = -\frac{1}{\omega C_g}, \quad e = R_0, \quad f = -\frac{1}{\omega C_g} - \frac{1}{\omega C_m}$$

(6) now becomes

$$0 > \frac{1}{\omega^2 C_p^2} \cdot \frac{1}{\omega C_g}\left(\frac{1}{\omega C_g} + \frac{1}{\omega C_m}\right)$$

and regeneration is impossible, therefore, when the input and load impedance are both constituted as capacitances.

SUMMARY OF CASES WHERE FEEDBACK OCCURS.

Of the above nine cases, only four present arrangements where regenerative feedback can take place. These are tabulated below with the necessary conditions for the existence of such feedback.

$Z_{input.}$	$Z_{output.}$	Condition for regenerative feedback.
Resistance $= R_g$	Inductance $= L_p$	$\omega^2 L_p C_m R_g < R_0$
Inductance $= L_g$	Inductance $= L_p$	$\omega^2 L_g C_m < 1$
Inductance $= L_g$	Resistance $= R_p$	$\omega^2 L_g C_m < 1$
Inductance $= L_g$	Capacity $= C_p$	$\omega^2 L_g C_m < 1$

CONDITIONS FOR MAXIMUM FEEDBACK.

The condition for maximum feedback effect can be determined in any general case from (5) by noting that the real part of the latter expression must then be maximum. The condition is determined as usual by equating the first derivative to zero, and solving the resulting equation for the variable used in the differentiation. It is useful to examine the four special regenerative cases presented above in this way.

Case A.—Z_i = Resistance. Z_o = Inductance.

Applying the differentiation to the real part of (5), under consideration that the variable is the plate circuit reactance ($= \omega L_p = b$), and solving, we get as value of this reactance giving maximum feedback

$$b = \omega L_p = e\left\{\frac{c(f^2 + c^2) \pm \sqrt{c^2(f^2 + c^2)^2 + f^2(f^2 + c^2)\,(f^2 - 3c^2)}}{f\,(f^2 - 3c^2)}\right\} \quad . \quad (17)$$

or

$$\omega L_p = e\sigma = R_0\sigma \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

wherein σ is the bracketed expression, and f, c, and e have the significance

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given above as

$$f = -\frac{1}{\omega C_m} \qquad c = R_g \qquad e = R_0$$

It is evident that this optimum value of ωL_p depends very materially upon the ratio of f to c, that is of the reactance of the grid-plate capacity to the supply circuit resistance. If we let $f = kc$ the value of σ can be written as a function of k

$$\sigma = \frac{(k^2+1) \pm \sqrt{(k^2+1)^2 + k^2(k^2+1)(k^2-3)}}{k(k^2-3)} \quad . \quad . \quad . \quad (19)$$

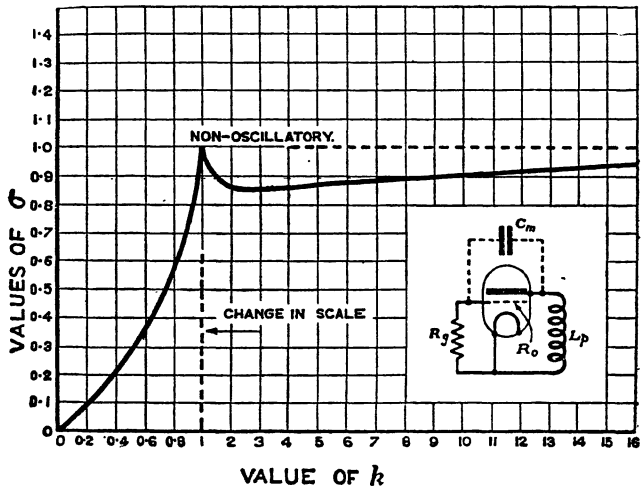

FIG. 3.—CONDITIONS FOR MAXIMUM FEEDBACK.

For oscillation $\omega L_p/k < R_0$ where $k = \frac{1/\omega C_m}{R_g}$.

In Fig. 3 this function is shown graphically for values of k from 0 to 15, and gives at once in terms of R_0 the value of plate circuit reactance required for maximum feedback. It will be noted that (19) is double valued. Only those values are plotted which fall within the feedback condition. When $k = 1$, that is $1/\omega C_m = R_g$, the value of ωL_p for maximum regeneration is just equal to the tube resistance R_0. This case is critical and does not feed back. A smaller value of ωL_p must, therefore, be used and the maximum feedback indicated cannot quite be obtained.

It has been pointed out that the real part of (5) is proportional to the feedback voltage. The value of this component has been calculated for different values of plate circuit load for the present case of resistance in the grid and inductance in the plate, and plotted in Figs. 4 and 5. The plate resistance is taken as 20,000 ohms, which corresponds to the standard Signal Corps type VT-1 receiving vacuum tube. As parameter is used the important ratio k of $1/\omega C_m$ to R_g. Fig. 4 is drawn for several cases where $1/\omega C_m$ is less than R_g, as for high frequencies, while Fig. 5 shows the conditions for $1/\omega C_m$

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greater than R_g as for low frequencies. The largest feedbacks are obtained when $1/\omega C_m$ and R_g are in the neighbourhood of equality with one another.

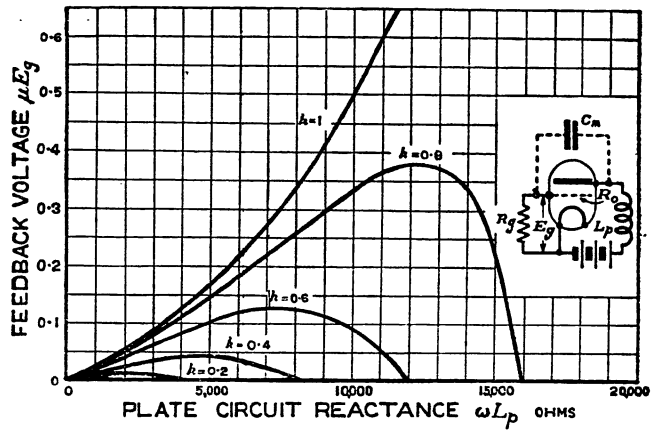

FIG. 4.—FEEDBACK VOLTAGES WITH VT-1 TUBE.

Cases for $1/\omega C_m < R_g$. $k = \dfrac{1/\omega C_m}{R_g}$ $R_0 = 20{,}000$ ohms.

For regeneration $\omega^2 L_p C_m R_g < R_0$.

The range of plate circuit load ωL_p over which feedback occurs, increases in general with increase in the ratio of $1/\omega C_m$ to R_g.

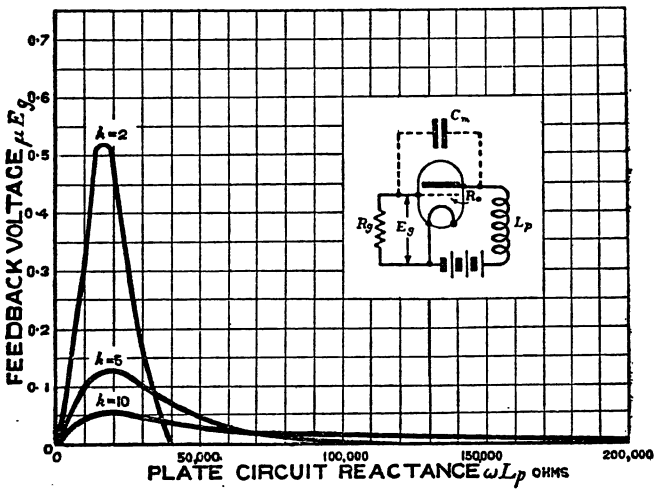

FIG. 5.—FEEDBACK VOLTAGES WITH VT-1 TUBE.

Cases for $1/\omega C_m > R_g$. $k = \dfrac{1/\omega C_m}{R_g}$ $R_0 = 20{,}000$ ohms

For regeneration $\omega^2 L_p C_m R_g < R_0$.

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Case B.—Z_i = Inductance. Z_o = Inductance.
In this case the feedback voltage (being the real part of (5)) becomes

$$E_g' = -\frac{b^2 d}{(b^2 + e^2) f} \cdot \mu E_g \quad \ldots\ldots\ldots (20)$$

where $b = \omega L_p, d = \omega L_g, e = R_0, f = \left(\omega L_g - \frac{1}{\omega C_m}\right) = d - f', f' = \frac{1}{\omega C_m}$
(20) can be put into the form (21)

$$E_g' = -\frac{b^2}{(b^2 + e^2)\left(1 - \frac{f'}{d}\right)} \cdot \mu E_g \quad \ldots\ldots\ldots (21)$$

It is evident that the ratio of f' to d is important as regards the magnitude

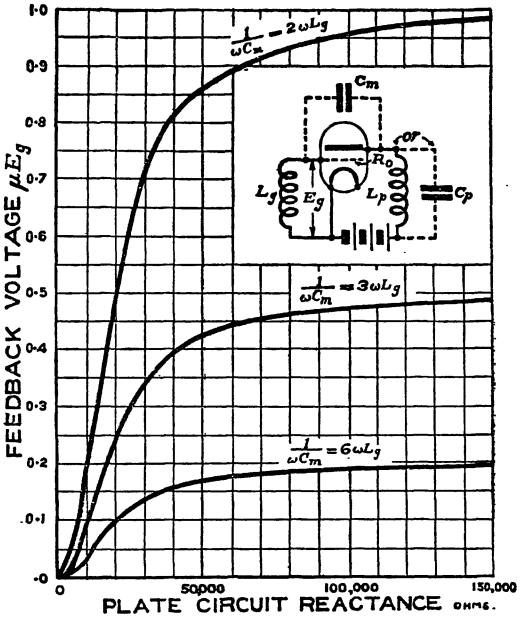

FIG. 6. — FEEDBACK VOLTAGES WITH VT-1 TUBE.
Plate Circuit Reactance = ωL_p or $1/\omega C_p$ ohms.
R_0 = 20,000 ohms. For Regeneration $\omega L_g < 1/\omega C_m$.

of feedback voltage. By (15), however, d must always exceed f' or the reaction will be counter-feedback. For all regenerative values of the ratio f'/d the feedback voltage increases with the plate circuit loading ωL_p ($= b$).

On Fig. 6 is plotted the feedback voltage E_g' as calculated from (21) for different values of f'/d and b. The curves resemble the magnetisation curves of iron in shape. The feedback voltage quickly approaches a limiting value

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and is not greatly increased by increasing the plate reactance beyond a certain point. For these calculations R_0 was taken as 20,000 ohms corresponding to the VT-1 tube.

Case C.—Z_i = Inductance. Z_o = Resistance.

The feedback voltage (real part of (5)) in this case is

$$E_g' = -\frac{ad}{ef} \times \mu E_g = -\frac{a}{e\left(1-\frac{f'}{d}\right)} \cdot \mu E_g$$

$$= -\frac{R_p}{R_0+R_p} \cdot \frac{1}{\left(1-\frac{f'}{d}\right)} \cdot \mu E_g \quad \ldots\ldots\ldots \quad (22)$$

This is plotted on Fig. 7 for the VT-1 tube (R_0 = 20,000 ohms) as function of R_p, and with f'/d as parameter. It is seen that the feedback can be increased by either increasing the plate load R_p or the grid supply circuit reactance ωL_g.

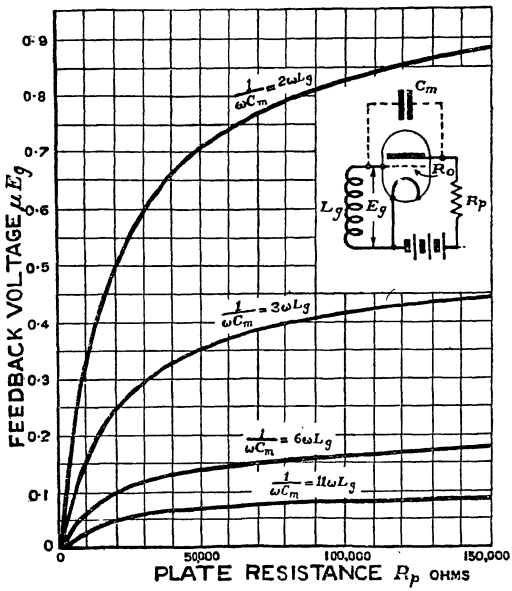

FIG. 7.—FEEDBACK VOLTAGES WITH VT-1 TUBE.
R_0 = 20,000 ohms. For regeneration $\omega L_g < 1/\omega C_m$.

Case D.—Z_i = Inductance. Z_o = Capacity.

The expression for feedback voltage in this case is identical with that of case B wherein the plate load is an inductance instead of a capacity. The conclusions for case B, and the curves referring thereto (Fig. 6) apply without change to the present situation if the plate circuit inductive reactance of case B ($= \omega L_p$) is now replaced by the capacity reactance $-1/\omega C_p$.

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Local Errors in Radio Direction Finding.*

By J. HOLLINGWORTH, M.A., and B. HOYLE, M.Sc., A.M.I.E.E.

Now that radio direction finding, using multi-turn coils with a length of side of only a few feet, has become a practicable possibility owing to the use of powerful amplifiers, attention is directed to the question of the reliability of such sets under working conditions, and to a closer investigation of the errors which are found to arise. Such errors are of course due to a large number of different causes and some of them may be under the control of the operator, but some are certainly not. It is of great importance that both these types of error should be fully investigated, in order that it may be possible to foretell the conditions under which reasonably accurate work can be expected, and what precautions must be taken to ensure a definite standard of reliability being obtained. At present it is believed that these errors are due to two causes:—

(*a*) Deviation of the waves during their passage through space.

(*b*) Local interferences at the receiving end.

The first of these is probably incurable; it is at present under investigation by various observers, and a large amount of information in the form of observations has been obtained; but it is hardly yet possible to generalise from these, and state in detail the causes of such trouble, and the limitation they enforce upon satisfactory work.

It is the second of these causes which will be dealt with in this paper. There is no doubt that for theoretically perfect reception the receiving station should be at a large distance from anything in the nature of conductors or tuned circuits; but as this is not generally possible, it is important to see what effects may be expected to occur under any particular conditions. This problem has not yet been investigated on its own merits for two reasons.

First, it is in the nature of an error; and so any observer, whose immediate object is the investigation of some other problem, is merely concerned with the question of its elimination. In setting up a direction finding station for accurate measurements the most favourable site available is generally chosen. If, then, a difference is found to occur between the measured and the calculated directions of the various stations, the receiving gear is moved, or the most obvious causes of interference taken away and any errors which cannot thus be eliminated are treated as due to causes beyond control. So long as they are permanent and constant they are not serious, and can be allowed for as soon as the mean error has been determined by a large number of observations. The object in view in this case is always to eliminate the errors, not to examine them; and once the errors have been reduced to an extent which does not interfere with the experiment in hand, no further attention is paid to them. The second reason is that to produce artificially in a measured form all possible disturbing conditions to which a direction finding station might reasonably be expected to be liable in practice, would

* Received May 14th, 1920.

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require enormous equipment and very great facilities. It seems, therefore, that the most practicable way of investigating this problem is by collecting together the results obtained by different observers during the time when they were setting up their stations and making preparations for their individual experiments. Each observer who finds such errors arising should take particular note of them, and of the methods which he used for their elimination. In this way a body of information could be collected from which it might be possible to deduce general laws. Such observations have been taken in many cases, especially where apparatus has been under design which would be required to work under specially unfavourable conditions; but in reading the literature of the subject the authors have been particularly struck with the enormous diversity of opinion on the magnitude and causes of such errors. They do not suggest that any of these observations are wrong, but that the favourable results obtained in some cases have been due to particular conditions which have not been fully investigated. Naturally, if only a small error is found when experience would seem to suggest that a large one was to be expected, this has been accepted as a fortunate circumstance, and the question of why the errors were unusually small in this particular case has not been investigated further. For instance, one observer states that a large aerial with a leading in wire, 20 feet from the coil even when tuned to the same wavelength as the coil, gave rise to an error not exceeding one-half of a degree; whereas one of the authors has met with a case in which an error of 4° was clearly produced by a tuned aerial at a distance of a quarter of a mile. They suggest therefore, that observers should take particular note of errors occurring in their own experiments, and publish them, so as to provide the body of information mentioned above.

Following out this idea the following paper merely recounts their personal experiences in this matter; and any general inferences which may be drawn from these results are only tentatively put forward.

It will probably be generally admitted that the ordinary local errors may be grouped under one or other of the following four headings; but the line of demarcation is not always very sharp.

(1) Masses of metal.
(2) Large conducting or partially conducting surfaces.
(3) Tuned circuits.
(4) Long distance overhead telegraph and telephone wires.

Section 1. Masses of Metal. (Especially iron; the extreme case being that of an iron ship.)—In this case an error appears to be always present, the order of it being not more than 10° under ordinary conditions. Such an error, so long as it is not affected by movable metal parts, can always be obtained by actual measurement and a correction chart supplied for directional work. It is only in the case where the movements of such parts produce changes in the correction that directional work becomes impossible. Experience seems to show that this correction is not seriously affected by the movement of any piece of metal-work of reasonable size, provided that it is some feet from the coil. As an instance of this may be taken the case of a coil inside the fuselage of an aeroplane and a coil on or above the deck of a

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battleship. In one particular instance of the former case where the coil was at the same level as the petrol tanks and only 4 or 5 feet from them, there was nothing in the general shape of the error curve to suggest that these large masses of metal, though close to the coil, were producing any individual effect. When, however, two bombs and two Lewis guns were mounted on the plane, the latter not more than 18 inches from the coil, obvious "humps" became visible on the correction curve. In the case of a two-engined aeroplane no special irregularity is noticed when one engine is nearly in line with the incoming waves. In the case of a battleship, if the coil is fitted in the space between the funnels about 30 feet above the deck, the necessary correction is uninfluenced by the movement of the guns. In this case, however, the error, though permanent, is large; and it has been found that by use of large coils on the Bellini-Tosi method, this permanent error is very much reduced. This again suggests that the errors produced are confined to a small space in the neighbourhood of the source of disturbance.

Variable errors have at times been obtained in aeroplanes; but are generally considered to be due to bad bonding of the bracing wires, which form large closed loops whose resistances vary with the state of the bond.

Section 2. Large Conducting Surfaces.—It is somewhat difficult to draw the line between (1) and (2). In this paper group 2 is intended to refer to the case of iron buildings in the immediate neighbourhood of the coil; or to the case of a coil used in or on a permanent building containing the usual metal-work. Under ordinary conditions no visible errors appear due to this cause, and two cases of this can be instanced. It was required to determine the correction curve of a flying boat at an aerodrome where the only firm ground in the neighbourhood available for the purpose was a space practically surrounded by large iron hangars at a distance of 50 to 100 yards. On a first inspection it was thought that this position was impracticable for the purpose, owing to deflection of incoming waves by the buildings; and that the boat would have to be tested at sea, which was not desired, owing to the many special difficulties of such an operation. On testing, however, with a small portable coil having an accuracy of 1°, receiving from stations in all directions, no measurable errors were noticed. In another case, a coil was mounted at the top of a building on a flat portion of a metallic roof, and, though it was quite unsymmetrically situated, no errors were visible. Inside an iron building it is a different matter, though the deviation does not appear to be very serious if the building is completely enclosed with metal-work; but in a metal shed with one end open, the waves from all stations appear to be deflected along the axis of the shed. Of course in ordinary circumstances no coil would be used in such conditions. In one case it was noticed that a copper mine caused bearings passing in the neighbourhood of it to be deflected about 3° and in another case such an effect is suspected, though the evidence is not conclusive.

Section 3. Tuned Circuits.—This heading includes both external circuits tuned to the same or nearly the same wavelength, and also radiation from parts of the receiving circuit itself. When using a transformer amplifier any movement of this may make considerable difference in the bearings,

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unless the amplifier is shielded or several feet from the coil. The objection to the former method is, that such shielding must be bulky and heavy, and if it is brought too close to the radiating coils of the amplifier, sufficient energy is absorbed from them to reduce the amplifying power considerably. It also tends to form a mass of metal in the immediate neighbourhood of the coil such as has been dealt with in section (1). The latter method involves the use of long leads, which, if close together, increase the capacity of the tuned circuit and if far apart tend to pick up energy on their own. Closed coils tuned to the same wavelength appear to have a serious effect at a distance of several feet; open aerials at a much greater distance. In the case of a coil underneath an aerial tuned to the same wavelengths as the aerial, incoming waves were deflected up to 45° in the direction of the aerial. With the coil slightly to one side of the aerial, all signals whose true direction was within 15° of the line from the coil to the leading-in wire of the aerial were deflected so as to appear to come directly from the leading-in wire. This wire was at a distance of about 150 yards from the coil. No visible effect is produced if the aerial is tuned to a wavelength greater than twice the wavelength of the coil, or if the aerial is insulated, or earthed in an untuned condition. In the case of an aerial at some distance (see Fig. 1) the following results have been obtained.

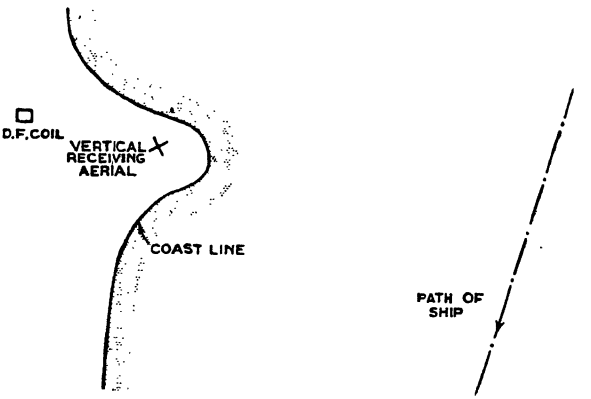

FIG. 1.

The coil was at a distance of a quarter of a mile from the aerial, and both were working on the same wavelength of 600 metres. Ships passed on the far side of the station from the aerial. When the observed angle subtended by the ship and aerial at the coil was about 4°, tuning in the station shifted the apparent bearing of the ship exactly on to the station. As before, no effect was noticed with an untuned aerial, whether earthed or insulated, proving that this effect was really due to the aerial, and not to any other local cause. This effect would of course diminish rapidly with increase of the angle subtended at the coil between the directions of the aerial and of the incoming waves, and it is probably due to this fact that the very large discrepancies of opinion which are referred to above have arisen. More information on this subject is required.

Section 4. Telegraph and Telephone Lines.—This is probably the most difficult case of all, from which to draw definite conclusions. It is not possible to remove or modify the arrangements of the wires in order to see

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to what extent they are the actual causes of the disturbances, and it is also impossible to obtain their electrical constants.

In certain definite cases very serious effects have been observed but there is nothing to show the limits within which such effects are likely to occur. The effect does not appear to be particularly due to single wire lines with an earthed return, as one of the worst cases noticed, which will be referred to in detail later, was that of a field telephone line wired with twin flexible not deliberately earthed at any point.

In many cases, however, sufficient capacity to earth is probably introduced through the telephone instruments themselves, especially if they are fitted with any kind of lightning protector, to make it possible for the line to be treated for W/T purposes, as if it were earthed at the end.

It is also uncertain whether the effect that occurs is due to the absorption of energy by the closed loop, or to a slight and very flat tuning effect which would give rise to re-radiation.

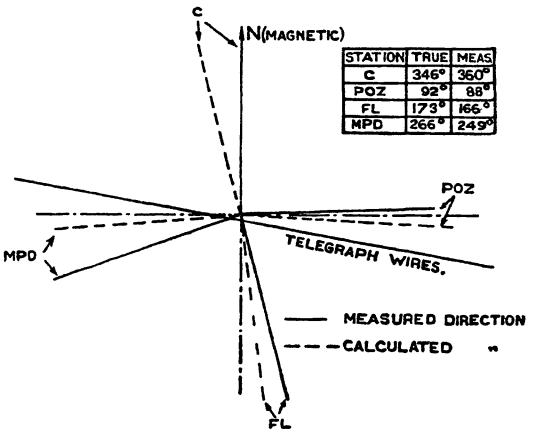

FIG. 2.

The characteristic effect of the former is that the incoming signal is deflected in such a way as to make it appear to come from a direction more nearly at right-angles to the wire than its true direction, owing to the absorption by the wire of the component of the wave in the direction of its length while the component at right-angles to the wire remains unaltered. On the other hand the effect of re-radiation on a circuit close to the source is to increase this component and so turn the direction of the signal towards the direction of the wire as in the case of a coil to a tuned aerial. As far as is known very little organised attention has been devoted to this problem, but the following two illustrations of results obtained are given.

The first was obtained in an odd half hour while waiting for a certain station to start working for a special test. It was not possible to devote further time to it and the results were not followed up. A small directional coil being available, it was placed on the ground at various distances from a line of wires carrying about half a dozen ordinary post office circuits. In one direction these wires extended for several miles, in the other direction in about half a mile they crossed the mouth of a river by means of a submarine cable. Consequently at this end the capacity to earth was very high and for wireless purposes they may be considered to have been earthed. Several

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stations were sending from various directions and measurements were taken as is shown in Fig. 2.

The diagram is practically self-explanatory. The coil was on the north side of the wires at a distance of about 2 yards from the line of poles which were of the usual height. It shows that very large errors were produced; and with one exception, FL, the tendency was to divert all the directions towards the normal to the wires, but it is quite unsafe to generalise from such a small number of results. The coil was afterwards moved to a distance of 7 yards from the line of wires, but at that time only one station, POZ, was sending, and from a single result little information can be obtained.

Another interesting case is shown in Fig. 3. Four small temporary huts used for wireless purposes were linked up as in the drawing by a field telephone set, the wiring consisting entirely of twin wire carried either on temporary poles or on hedges. In hut A, there was a three line exchange and also the coil with which the tests were made. By operating this exchange the bearing could be shifted into almost any direction required. If all the lines terminating at A were left open the effect was quite small, but if hut B were switched to hut D, the direction of signals from Paris was shifted 14°.

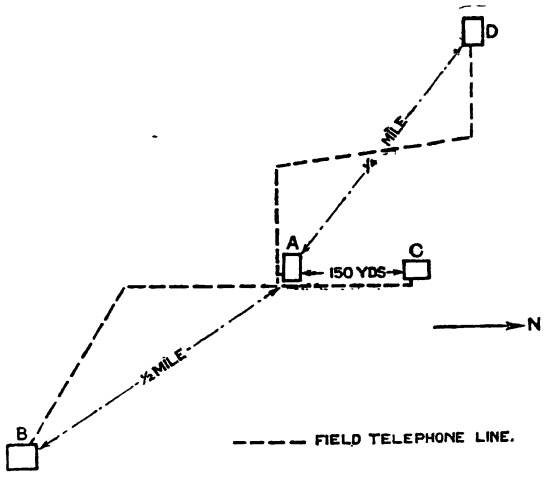

FIG. 3.

Other arrangements of the switchboard produced different deflections, none of which were quite so serious, but still were sufficient to make work impossible. A hut used for directional purposes nearly always required a telephone for convenience in operating and reporting, and this seems to show that for safety it is necessary that telephone lines must run underground for at least several hundred yards from the hut. The magnitude of the results is so difficult to foretell that it is necessary to err on the side of extreme caution.

To summarise, one may say that local variations may be due to a large number of causes. Some of these are permanent and consequently not so serious, but others, like the one last described, may vary without the knowledge of the operator and so lead to totally wrong inferences. Of course when a large permanent directional station is being erected it is generally possible to choose a site free from such troubles, but at the same time it is of great value to know the conditions under which it is possible to take temporary measurements with a reasonable degree of accuracy.

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An Elementary Method of Deducing the Effect of Resistance in Damping Oscillations.*

By E. GREEN, M.Sc.

If a circuit consisting of inductance L, capacity C, and resistance R is set in oscillation and afterwards left to itself the resultant variation of the current with time is as shown in Fig. 1. The usual method of determining the ratio of current amplitudes after any number of oscillations is by reference to the equation for current

$$i = I_0 \epsilon^{-bt} \cos pt$$

which in turn is obtained from the solution of a certain differential equation. But it is possible to find the ratio of current amplitudes from more elementary considerations with a fair degree of accuracy.

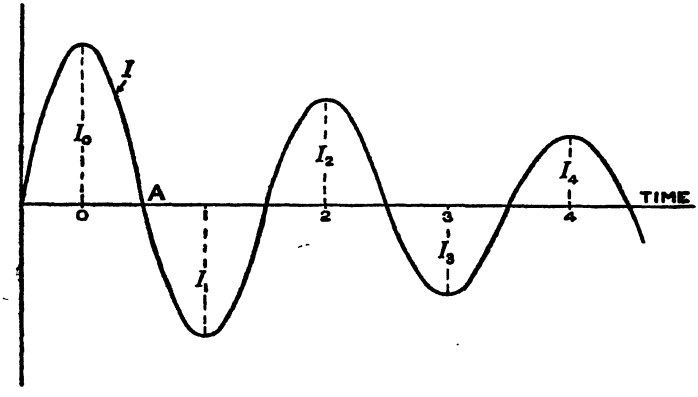

FIG. 1.

At the instants represented by 0, 1, 2, etc., when the current is a maximum, the voltage across the condenser is zero and the whole of the energy is concentrated in the inductance.

$$\text{Energy in circuit at } 0 = \tfrac{1}{2}LI_0^2$$
$$\text{,, ,, } 1 = \tfrac{1}{2}LI_1^2, \quad \text{etc.}$$

Between these two points the energy lost in resistance must be $\frac{1}{2}LI_0^2 - \frac{1}{2}LI_1^2$.

Let T = the time of one complete oscillation so that times from 0 to A and A to 1 are each $T/4$.

During the time 0 to A we can regard the current as a sinusoidal one with a maximum value I_0; and from A to 1 as having a maximum value I_1.

$$\therefore \text{ Resistance losses from 0 to A} = \tfrac{1}{2}RI_0^2 \times \frac{T}{4} = \frac{RT}{8}I_0^2.$$

$$\text{Similarly resistance losses from A to 1} = \frac{RT}{8}I_1^2.$$

* Received May 1st, 1920.

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$\therefore \frac{1}{2}LI_0^2 - \frac{1}{2}LI_1^2 = \frac{RT}{8}I_0^2 + \frac{RT}{8}I_1^2$, which on rearranging becomes

$$\tfrac{1}{2}LI_0^2\left\{1 - \frac{RT}{4L}\right\} = \tfrac{1}{2}LI_1^2\left\{1 + \frac{RT}{4L}\right\}.$$

Put $\frac{RT}{4L} = \delta$ which is the logarithmic decrement per half period, so that

$$\tfrac{1}{2}LI_0^2\{1 - \delta\} = \tfrac{1}{2}LI_1^2\{1 + \delta\}.$$

$$\therefore \frac{I_1}{I_0} = \sqrt{\frac{1-\delta}{1+\delta}} = k.$$

When R, L and T are known, δ and therefore k can be determined. The same reasoning holds good in the case of I_1 and I_2, etc.

$$\therefore \frac{I_1}{I_0} = \frac{I_2}{I_1} = \frac{I_3}{I_2} = \ldots\ldots = k$$

Hence $\frac{I_n}{I_0} = \frac{I_1}{I_0} \times \frac{I_2}{I_1} \times \ldots\ldots = k^n$ and can be determined.

It is of interest to see how closely these results agree with the more accurate formula.

$$\frac{I_1}{I_0} = \sqrt{\frac{1-\delta}{1+\delta}} = 1 - \delta + \tfrac{1}{2}\delta^2 - \tfrac{1}{2}\delta^3 + \ldots\ldots$$

From the accurate formula

$$\frac{I_1}{I_0} = \epsilon^{-\delta} = 1 - \delta + \tfrac{1}{2}\delta^2 - \tfrac{1}{6}\delta^3 + \ldots\ldots$$

Hence the error by the approximate method is of the order of $\frac{1}{3}\delta^3$.

δ	Error.
0·1	0·03 per cent.
0·2	0·3 ,,
0·3	1 ,,

The approximate formula is therefore accurate enough for all practical cases. It should be remembered however that in finding the value of k^n the percentage error will be approximately n times as large.

The chief interest of the approximate method lies in its showing clearly from the energy relations how the various constants of the circuits affect the damping.

[In applying the strictly accurate decrement formula to circuits containing a spark-gap, the assumptions made are so incorrect that the further assumption made in the above note is quite permissible.

We might point out however that in a damped oscillation the voltage across the condenser is not zero when the current is a maximum. The current begins to decrease as soon as the rate of energy transfer from the condenser to the magnetic field falls below the rate of energy dissipation in the circuit; at this moment $Ci\frac{dv}{dt} = i^2R$ and v cannot be zero.—Editor.]

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Measurement of the Field Strength at Leghorn of the Annapolis Signals. The Need for Further Research.

By THE EDITOR.

In August, 1919, measurements were made at the radiotelegraphic laboratory of the Italian Navy at Leghorn with the object of determining the strength of the electromagnetic field produced there by the transmitting station at Annapolis, U.S.A. The method adopted by Professor Vallauri was as follows:—Two single-turn vertical coils, triangular in shape and having each an area of 1,404 square metres, were supported by masts in such a way that one was in the great-circle plane through Leghorn and Annapolis, whilst the other was at right-angles thereto. The signals were therefore received only on the former, and, as tests with amplifiers proved, no trace of the signals could be detected on the latter. The receiving circuits are shown in Fig. 1. The primary circuit consists of one of the triangular aerials, eight

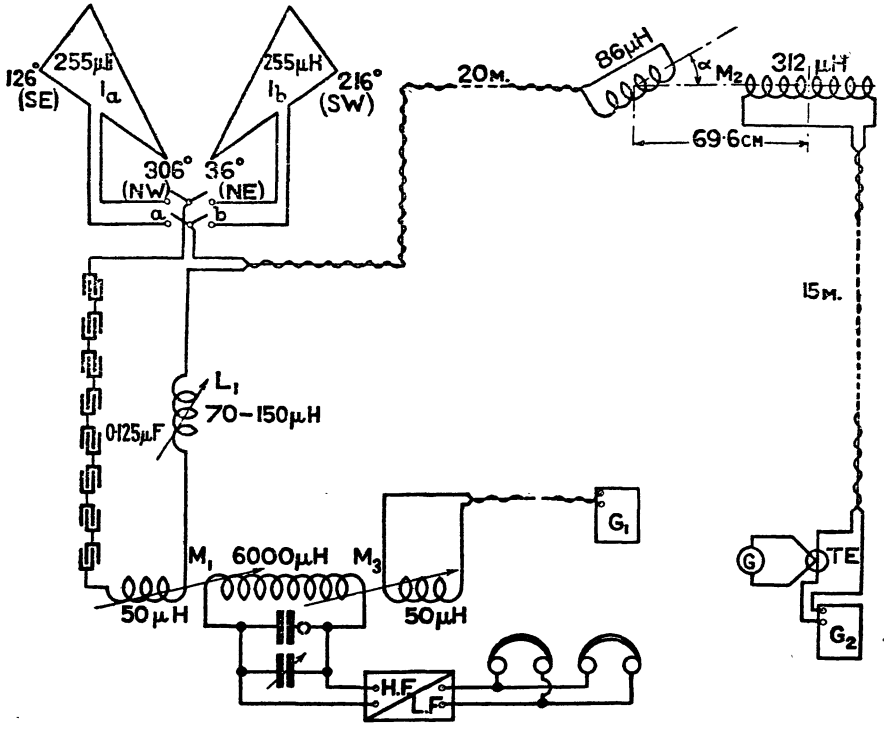

FIG. 1.

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condensers of 1 μF in series, a coupling coil of 50 μH, a variable inductance of 70—150 μH and a second coupling coil of 86 μH. The secondary circuit consists of an inductance of 6,000 μH, with the necessary condensers, across which is connected the amplifying detector set with six high frequency and two low frequency stages. G_1 is an oscillating valve set for independent heterodyne reception, whilst G_2 is a similar set, the output current of which is measured by means of the thermo-junction TE and galvanometer G. This current passes through the coil of 312 μH, which forms the primary of the variable and carefully calibrated mutual inductance M_2, of which the coil of 86 μH forms the secondary.

With the switch a b in one position and G_2 out of action, the signals from Annapolis are received and their pitch and intensity adjusted by means of the heterodyne generator G_1; with the switch in the other position, Annapolis cannot be heard, but G_2 is started up and its frequency adjusted until the same note is obtained in the receivers; the mutual inductance M_2 is then adjusted until the signals are equal in strength to those received from Annapolis, when the switch a b is in the other position. Knowing the value of the mutual inductance M_2 and the current in its primary coil, the E.M.F. induced in the aerial circuit can be calculated. With the switch a b in the other position the same E.M.F. must be produced by the Annapolis signals, and from the area of the aerial the strength of the electromagnetic field can be calculated. Precautions must be taken to ensure that no interference occurs due to mutual inductance between various parts of the circuits. Most of the measurements were made when the transmitting key at Annapolis was held down.

The effective height h of the Annapolis aerial is 0·107 km. and the current 280 amperes; hence $hI = 30$. The distance between Annapolis and Leghorn is 6,917 km.; the wavelength employed 17·3 km. Austin and Cohen had found that the received current was obtained by multiplying the value calculated on the assumption of a plane conducting earth and an ideal atmosphere of infinite extent by the exponential factor $\epsilon^{-0\cdot0015D/\sqrt{\lambda}}$. **Professor Vallauri's measurements gave values of the electromagnetic field varying from 6 to 18 times as great as those calculated by the Austin-Cohen formula.** In view of this discrepancy Professor Vallauri sent us particulars of his experiments and data; we came to the conclusion that the results were probably correct, since, on trying various alternatives to the Austin-Cohen factor, we found that Vallauri's results were in excellent agreement with the exponential factor suggested by L. F. Fuller (*Proceedings of the American Institute of Electrical Engineers*, 34, pp. 567—585, April, 1915), viz., $\epsilon^{-0\cdot0045D/\lambda^{1\cdot4}}$. We communicated this fact to Professor Vallauri, who has now published his results with the values calculated by the two methods in parallel columns (*L'Elettrotecnica*, 7, pp. 298—300, June 15th, 1920). Using the measured values of the field strength, he calculates the value of the product hI of the Annapolis aerial, which we know to be about 30. He gives 31 observations made at different times during the day and night; using Fuller's formula the calculated values vary between 24 and 75, whereas the Austin-Cohen formula

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gives values between 170 and 530, that is, about ten times the measured value. The Austin-Cohen formula would therefore lead to values 100 times too great for the necessary power required to produce the received signals.

Over what range of distances and wavelengths Fuller's factor is applicable there is not sufficient data to decide. For a wavelength of about 3·5 km. both formulæ give the same result, for longer wavelengths the Fuller formula is the more optimistic, whereas for shorter wavelengths the reverse is the case. In our last issue we gave tables and curves of the power required for long distance transmission based on the Austin-Cohen formula. We have recalculated the tables on the assumption that Fuller's formula is applicable throughout, and the results are embodied in Tables I. and II.

On comparing these tables with those given in our last issue, it will be seen that if Fuller's exponential be assumed, the calculated power required to cover distances of 5,000 to 10,000 km. is a mere fraction of that calculated

TABLE I.

Aerial power in kilowatts to give 0·37 microvolts per centimetre ($\beta = 0{\cdot}1$).

λ_m	D = 1,000 km.					
	$\gamma = 0{\cdot}5$	$\gamma = 0{\cdot}75$	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$
0·5	—	—	—	2,230	140	45·5
1·0	—	—	405	8·07	5·8	9·8
2·5	14·1	1·26	0·585	0·695	1·47	5·0
5·0	0·234	0·124	0·126	0·388	1·06	4·26
10·0	0·051	0·052	0·071	0·313	0·94	4·02

λ_m	D = 2,000 km.						D = 3,000 km.					
	$\gamma = 0{\cdot}5$	$\gamma = 0{\cdot}75$	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$	$\gamma = 0{\cdot}5$	$\gamma = 0{\cdot}75$	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$
0·5	—	—	—	—	—	2,130	—	—	—	—	—	56,000
1·0	—	—	—	948	155·5	99	—	—	—	63,500	2,340	562
2·5	—	207	27·4	7	9·9	25·8	—	—	720	39·8	37·6	75
5·0	11	2	1·3	2·2	5·15	18·7	288	18·1	7·25	7·0	14·1	46·4
10·0	0·51	0·35	0·4	1·43	4·03	16·7	2·89	1·32	1·27	3·65	9·76	39

λ_m	D = 5,000 km.						D = 10,000 km.			
	$\gamma = 0{\cdot}5$	$\gamma = 0{\cdot}75$	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$	$\gamma = 1$	$\gamma = 2$	$\gamma = 3$	$\gamma = 5$
1·0	—	—	—	—	290,000	10,050	—	—	—	—
2·5	—	—	274,000	710	298	346	—	291,000	16,400	4,930
5·0	110,000	835	129	39	58	155	53,000	773	617	1,000
10·0	52	10·4	7·05	13·2	31·5	116	159	101	183	555

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Table II.

Optimum wavelength and minimum aerial power in kilowatts to give 0·37 microvolts per centimetre ($\beta = 0{\cdot}1$).

D km.	$\lambda_m = 1$			$\lambda_m = 2{\cdot}5$			$\lambda_m = 5$			$\lambda_m = 10$		
	γ	λ	P	γ	λ	P	γ	λ	P	γ	λ	P
1,000	2·5	2·5	5·6	1·25	3·125	0·5	0·75	3·75	0·12	0·5	5·0	0·05
2,000	4·75	4·75	99	1·5	3·75	6·5	1	5·0	1·28	0·75	7·5	0·34
3,000	6·0	6·0	510	2·5	6·25	36	1·5	7·5	6·0	1·0	10·0	1·27
5,000	—	—	—	3·0	7·5	298	2·0	10·0	38	1·15	11·5	6·5
10,000	—	—	—	6·0	15·0	4,740	2·5	12·5	600	2·0	20·0	100

on the assumption that the Austin-Cohen factor is applicable. Here then is a subject for international research; the experiments described above show that the requirements in the way of aerials and instruments are very modest. There need be no fear of overlapping; in our present state of knowledge the more overlapping there is the better. There are two distinct lines of research: firstly, to determine what strength of electric field it is necessary for signals to have to enable them to be read at all times in spite of atmospheric disturbances, and secondly to determine the law according to which electromagnetic waves of various lengths are propagated around the earth. The former will depend on the locality, on the direction of the transmitting station, on the type of aerial and devices employed for eliminating interference, on the wavelength and speed of working, and on the interpretation of the words "at all times." The latter line of research will involve considerations of diurnal and seasonal variations, the nature of the surface and the direction of propagation with respect to the parallels of latitude. Until such researches have been carried out, the design of long distance wireless systems on scientific lines is obviously impossible.

The British Association for the Advancement of Science.

The annual meeting of the Association was held at Cardiff from August 24th to August 28th. The only paper bearing directly on radiotelegraphy was read before Section G (Engineering) by Professor Howe, on "The Efficiency of Aerials and the Power required for Long-distance Transmission." This covered the same ground as the editorial articles in our August and September issues and in this number. In Section A (Mathematics and Physics) Professor Whiddington read a paper on the measurement of small changes of length by means of the variation in the capacity of an air condenser when the distance between the plates is changed.

The change of capacity can be detected by using two separate oscillating valve circuits, one containing the experimental condenser and the other a fixed condenser. Any change of the capacity will cause a change of frequency and therefore a change in the beat note in a receiving circuit coupled to both oscillating circuits.

Professor S. Chapman read a paper entitled, "Terrestrial Magnetism, Auroræ, Solar Disturbance, and the Upper Atmosphere." Although dealing with the ionisation of the atmosphere from the point of view of its effects on terrestrial magnetism, the paper will prove of interest to those interested in the physics of long-distance wireless transmission and atmospheric disturbances.

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Review of Radio Literature.

1. Articles and Patents.

859. ON ARTIFICIAL LINES. J. Bethenod. (*Radioélectricité*, 1, p. 128, August, 1920.)

Considerable interest has recently been expressed in the use of various forms of filters, or filtering circuits, for eliminating, or at least reducing, the effects of disturbances, such as atmospherics, in wireless receiving. The author points out that these circuits are merely special cases of ordinary artificial lines, and proceeds to deduce the filtering action of such lines, taking a general case with inductance and resistance in the shunt paths, and resistance and capacity in the series circuit, employing the ordinary electrical theory of branched circuits. He concludes that in effect such circuits are equivalent to a series of ordinary inductively coupled circuits having coefficients of mutual inductance equal to the self-inductances of the shunt branches. From this point of view the presence of resistances are a disadvantage. The favourable action of the filters can only be obtained by a series of adjustments of each branch in turn, and the author is of the opinion that the equivalent series of inductively coupled circuits may possess advantages from the point of view of ease of adjustment.

860. ANTENNA CONSTANTS AND THE WAVELENGTHS OF ANTENNÆ. A. Press. (*Revue Générale de l'Électricité*, 7, pp. 547—552, April 24th, 1920. *Science Abstracts*, 23B, p. 323, Abstract No. 636, June 30th, 1920—Abstract. *Technical Review*, 6, p. 588, July 6th, 1920—Abstract.)

The author first points out the variation of the inductance per unit length of an aerial with the height of the point considered above the ground. An expression is given for this function, and from a consideration of curves plotted therefrom it is shown that the mean values of the inductance in henrys per cm. for a vertical and for a horizontal wire may be written in the following forms :—

$$L_1 = 4{\cdot}6 \times 10^{-9} \left\{ \log_{10} \frac{2h_1}{a} - 0{\cdot}3 \right\} \quad \text{(vertical)}$$

and

$$L_2 = 4{\cdot}5 \times 10^{-9} \,.\, \log_{10} \frac{2h_1}{a} \quad \text{(horizontal).}$$

The differential equations are developed for an inverted L type of aerial and an expression is derived for the equivalent impedance of the aerial as a whole. This last may be written in the form

$$Z_0 = -j \frac{1}{2\pi f(C_1 h)} . \Gamma \quad \text{ohms.}$$

where f is the frequency, C_1 is the capacity per unit length of the vertical portion, h is the overall length of the aerial and Γ represents the following function :—

$$\Gamma = \frac{L_2}{L_1} \cdot \frac{\pi}{2} \cdot \frac{\lambda_0}{\lambda} \cot \frac{\pi}{2} \cdot \frac{\lambda_0}{\lambda} = \frac{L_2}{L_1} \cdot \frac{2\pi h}{\lambda} \cot \frac{2\pi h}{\lambda}$$

For long wavelengths the equivalent impedance Z_0 becomes that of a pure capacity while for short wavelengths (less than the fundamental λ_0) Z_0 represents a pure inductance. Curves are given for the function Γ and also for the ratio of L'/l_0 where L' is the inductance added in

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series at the base of the antenna and l_0 is the inductance per unit length of the vertical portion multiplied by the total length of the aerial.

The method of determining the equivalent inductance and capacity of an aerial as outlined by Eccles, in which wavelength measurements are made with an added inductance in series with the aerial, is critically discussed, and finally a calculation is given for the ratio L_2/L_1 for a multi-wire aerial, L_2 being the inductance per unit length of the horizontal portion and L_1 the corresponding quantity for the vertical portion. This ratio is shown to approximate to the value

$$1 + \frac{0{\cdot}3}{\log_{10}\frac{2h_1}{a} - \frac{N-1}{N}\cdot\log_{10}\frac{s}{a} - \frac{K_n}{N}}$$

where h_1 is the height of the horizontal portion above the ground, N is the number of wires in parallel, a is the radius of each wire, s is the width of the aerial and K_n is a factor dependent upon the number of wires. The values for this factor are tabulated below :—

N	K_n	N	K_n	N	K_n	N	K_n
		6	1·18	11	2·22	16	2·85
2	0	7	1·43	12	2·37	17	2·95
3	0·308	8	1·66	13	2·51	18	3·04
4	0·621	9	1·86	14	2·63	19	3·14
5	0·906	10	2·05	15	2·74	20	3·24

Some sample calculations illustrating the formulæ are included at the end of the article.

861. ABSOLUTE MEASUREMENT OF FREQUENCY OF ELECTRICAL OSCILLATIONS. J. Tykocinski-Tykociner. (*Science Abstracts*, 23A, p. 356, Abstract No. 909, June 30th, 1920—Abstract.)
See also RADIO REVIEW Abstract No. 328, May, 1920.

862. HIGH FREQUENCY RESISTANCE OF WIRES AND COILS. G. W. O. Howe. (*Science Abstracts*, 23B, p. 295, Abstract No. 585, June 30th, 1920—Abstract.)
See RADIO REVIEW Abstract No. 582, August, 1920.

863. THE LOW-FREQUENCY CYCLE IN MUSICAL SPARK TRANSMITTERS. F. F. Martens and G. Zickner. (*Jahrbuch Zeitschrift für drahtlose Telegraphie und Telephonie*, 15, pp. 266—288, April, 1920.)
A theoretical and experimental investigation of the conditions controlling the operation of a quenched spark transmitter with either one or two sparks per cycle. The wave forms of the currents and voltages were determined by means of a cathode ray oscillograph. A bibliography of the subject is given.

864. DIELECTRIC CONSTANT OF MARBLE. (*Zeitschrift für Instrumentenkunde*, 40, p. 119, June, 1920.)
A report of tests made at the Reichsanstalt. Natural marble absorbs moisture and its capacity depends on the frequency ; if paraffined before thorough drying it is even worse, but if thoroughly dried in vacuum (48 hours at 160°) and then paraffined its dielectric constant of 8·4 was independent of the frequency between $f = 146$ and $f = 572{,}000$.

865. SKIN EFFECT IN SQUARE WIRES. A. Press. (*Radio Review*, 1, pp. 466—467, June, 1920.)

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866. MEASUREMENTS OF THE ELECTROMAGNETIC FIELD DUE TO AN AEROPLANE TRANSMITTER. R. Baldus and R. Hase. (*Jahrbuch Zeitschrift für drahtlose Telegraphie und Telephonie*, 15, pp. 354—391, May, 1920.)

Signals were sent out from an aeroplane and the received strength determined at a ground station. A large number of experiments were made to determine the effects of distance, height, direction of flight, type of plane and aerial employed. Both vertical and horizontal receiving aerials were tried.

867. RELIABLE METHOD FOR THE APPROXIMATE DETERMINATION OF TRUE ANTENNA CONSTANTS. A. Hund. (*Science Abstracts*, 23B, p. 63, Abstract No. 130, January, 1920—Abstract.)

See RADIO REVIEW Abstract No. 92, January, 1920.

868. HARMONIC OSCILLATIONS IN DIRECTLY EXCITED ANTENNAS USED IN RADIOTELEGRAPHY. L. Lombardi. (*Science Abstracts*, 23B, pp. 107—108, Abstract No. 202, February, 1920—Abstract.)

See RADIO REVIEW Abstract No. 278, April, 1920.

869. REINFORCED HARMONICS IN HIGH-POWER ARC TRANSMITTERS. F. A. Kolster. (*Science Abstracts*, 23B, p. 112, Abstract No. 214, February, 1920—Abstract.)

See RADIO REVIEW Abstract No. 279, April, 1920.

870. AN OSCILLATING SOURCE FOR RADIO RECEIVER INVESTIGATIONS. J. Weinberger and C. Dreher. (*Science Abstracts*, 23B, p. 163, Abstract No. 328, March, 1920—Abstract.)

See RADIO REVIEW Abstract No. 275, April, 1920.

871. NOTES ON THE MEASUREMENT OF WAVELENGTH AND HIGH FREQUENCY INDUCTANCE AND CAPACITY. D. Williams. (*Wireless World*, 7, p. 582, January, 1920.)

The "double click" method of measurement is described.

872. ON MEASUREMENT OF SIGNAL STRENGTH. W. H. Eccles. (*Science Abstracts*, 23B, p. 166, Abstract No. 335, March, 1920—Abstract.)

See RADIO REVIEW Abstract No. 19, November, 1919.

873. THE MEASUREMENT OF HIGH FREQUENCY RESISTANCE. (I) COMPARISON OF DIFFERENT TYPES OF WINDING. L. M. Clement. (*Everyday Engineering Magazine*, 9, pp. 156—158, May, 1920.)

A number of measurements are summarised in the form of curves relating to different types of windings. The advantages of banked windings as compared with ordinary layer windings are well illustrated.

874. CONDUCTIVITY AND DIELECTRIC COEFFICIENT OF DIELECTRICS AT HIGH FREQUENCIES. G. E. Bairsto. (*Revue Générale de l'Électricité*, 7, p. 153D, May 15th, 1920—Abstract.)

See RADIO REVIEW, 1, Abstract No. 473, July, 1919.

875. APPLICATIONS OF THE CATHODE RAY TUBE IN RADIO WORK. L. E. Whitmore and L. M. Hull. (*Revue Générale de l'Électricité*, 7, pp. 173D—174D, May 29th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 181, February, 1920.

876. AN A.C. ZERO METHOD OF DETERMINING THE GRID SENSIBILITY OF AMPLIFYING VALVES. W. Schottky. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 31—32, May, 1920.)

The resistance x is adjusted until the alternator of telephonic frequency gives no sound in the telephone receiver T (see Fig. 1). Now $\delta i_p = \delta v_g \frac{\partial i_p}{\partial v_g} + \delta v_p \frac{\partial i_p}{\partial v_p}$.

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For no sound in the telephone, neglecting the resistance of the plate battery, $\delta v_p = 0$, $\therefore \delta i_p = \frac{\partial i_p}{\partial v_g} . \delta v_g$ but the A.C. grid potential $\delta v_g = \delta i_p \times x$, $\therefore \partial i_p / \partial v_g = 1/x$.

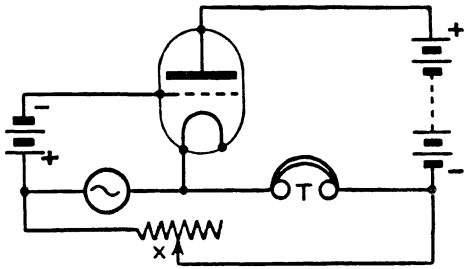

FIG. 1.

It is to be noted that by grid sensibility the author means the slope of the plate-current —grid-voltage characteristic.

877. THE CALIBRATION OF WAVEMETERS BY MEANS OF HIGHER HARMONICS. R. von Ettenreich. (*Jahrbuch Zeitschrift für drahtlose Telegraphie und Telephonie*, 15, pp. 236—240, March, 1920. *Science Abstracts*, 23B, p. 360, Abstract No. 695, July 31st, 1920—Abstract.)

The frequency of a moderately high frequency generator, say 5,000 cycles per second is determined accurately by ordinary means. It is loosely coupled to the wavemeter by an intermediate non-oscillating circuit containing a rectifier, *e.g.*, a crystal detector. This causes a great number of harmonics which can be used to calibrate the wavemeter.

878. BUZZER FOR WIRELESS TELEGRAPHY. C. Lorenz. (*German Patent* 301743, July 22nd, 1917. Patent granted October 1st, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 503, June, 1920—Abstract.)

An electromagnetic buzzer the coil of which is provided with a closed yoke.

879. SPARK TRANSMITTERS. Société Française Radio-Électrique. (*French Patent* 502159, March 18th, 1915. Published May 6th, 1920.)

The specification describes means of arranging spark producers for wireless telegraphy consisting of n spark producers in parallel. The discharges obtained at the said spark gaps are controlled so that each gap furnishes p/n discharges per second, p being the total number of discharges per second in the oscillating circuit. The control of the spark gaps is such that the discharges join up in the oscillation circuit and produce a frequency of discharge equal to p. No drawings are appended to the specification.

880. APPARATUS FOR PRODUCING ELECTRIC OSCILLATIONS. M. Deutsch. (*British Patent* 137564, December 19th, 1918. Patent accepted January 22nd, 1920.)

This specification deals with apparatus for the production of high frequency oscillations in which a vibrating make-and-break contact is shunted by an oscillating circuit including a condenser and the primary winding of a transformer. Provision is made for a part only of the electromagnet winding operating the vibrating contact to be included in the circuit when an A.C. supply is used, whereas the whole winding is employed with a D.C. supply.

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881. QUENCHED GAP OPERATION. H. J. Tyzzer. (*Everyday Engineering Magazine*, 9, pp. 154—155, May, 1920.)

Deals with the use of quenched spark gaps fed from an induction coil for short-wave transmission.

882. ELECTRIC ARC OSCILLATION GENERATORS. P. O. Pedersen. (*British Patent* 136762, May 29th, 1919. Convention date, March 4th, 1919. Patent accepted, December 24th, 1919.)

With a view to increasing the efficiency of an arc oscillation generator particularly in cases when it is used in conjunction with aerials of small capacity, it is proposed to limit the movement of the arc on the cathode by means of appropriate local cooling, or by special shaping of the cathode and positioning with respect to the anode, or by the provision of appropriately placed jets through which gas (such as hydrogen, coal gas, alcohol, etc.) may be blown on to the arc. The cathode may also be water cooled if desired or may be cooled locally by contact with an auxiliary water-cooled tube so that its temperature may be adjusted to give any desired high ignition voltage.

883. VALVE TRANSMITTING APPARATUS. General Electric Company, U.S.A. (*British Patent* 139640, March 26th, 1919. Patent accepted March 11th, 1920.)

The essential features of the arrangement described are indicated in Fig. 2, which aims at enabling the ratio of capacity to inductance in the oscillating circuit to be adjusted to the value at which the valve operates most efficiently independently of the value of the aerial capacity. For this purpose the filament of the valve V is joined to the centre earthed point

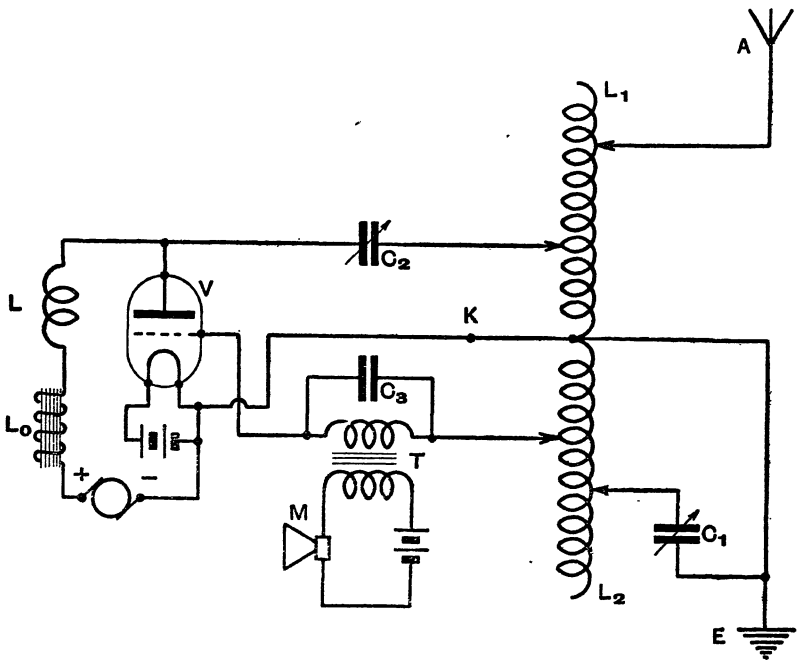

FIG. 2.

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of the inductance L_1 L_2 which provides the reaction coupling between the grid and anode circuits of the valve as indicated. The aerial tapping should be made to the part of the coil which is included in the plate circuit and an auxiliary condenser C_1 is similarly connected to a tapping on the grid side to the coil and adjusted so that the capacity of the aerial circuit is compensated for. For radiotelephone transmission the transmitting microphone is coupled to the grid circuit through the transformer T in the usual manner. The direct current supply circuit for the valve includes the iron core choke L_0 and a special choke inductance L which is so designed as to be in resonance for the oscillation frequency so that it offers an almost infinite impedance to the passage of currents of that frequency. For telegraphic signalling the transformer T may be omitted and the signalling key connected at K while the iron core choke L_0 may also be omitted.

884. VALVE OSCILLATION GENERATORS. E. O. Scriven. (*British Patent* 140449, March 18th, 1920. Convention date, June 4th, 1917. Patent not yet accepted but open to inspection.)

In a three-electrode valve arranged for generating oscillations with a usual arrangement of reaction coupling, a high resistance is connected in series with the plate circuit so that the current in that circuit is maintained practically constant in spite of the slight alterations in the conditions of operation of the valve, etc. This resistance may be replaced by a large choking inductance so that the harmonics in the oscillation may be emphasised in the output circuit which supplies an amplifying valve. Currents of higher frequency than the fundamental may be obtained by providing the output circuit of this amplifying valve with a number of parallel branch circuits tuned respectively to the harmonic frequencies of the fundamental oscillations.

885. THERMIONIC VALVE OSCILLATION GENERATORS. R. V. L. Hartley. (*British Patent* 141046, March 30th, 1920. Convention date, June 1st, 1915. Patent not yet accepted but open to inspection.)

The circuit described for the generation of oscillations by means of a triode valve is the well-known one in which the reaction between the anode and grid circuits is provided by a condenser connected between the anode and the grid, there being no mutual induction between the inductances in the anode and grid circuits. See RADIO REVIEW, 1, pp. 577—584, September, 1920.

886. TRANSMITTERS. J. Bethenod. (*French Patent* 501512, December 31st, 1918. Published April 16th, 1920.)

The specification describes a method of coupling an aerial to a high-frequency alternator and the patent corresponds to British Patent 128575.*

887. HIGH FREQUENCY INDUCTOR ALTERNATORS. E. F. W. Alexanderson. (*British Patent* 141745, April 16th, 1920. Convention date, June 22nd, 1915. Patent not yet accepted but open to inspection.)

In a high frequency alternator of the well-known Alexanderson type provision is made for the connecting together of the non-magnetic slot filling plugs on the rotor by connecting rings to form short circuited windings for minimising the effect of armature reaction. The widths of the stator and of the rotor teeth should be such that as the rotor rotates the number of rotor teeth opposite any stator tooth alternates between $\frac{1}{2}(n+1)$ and $\frac{1}{2}(n-1)$ where n is any odd integer greater than one. In the example quoted in the specification $n = 3$ and the number of inductor teeth opposite the stator teeth varies between one and two. The frequency of the induced current is then three times the frequency that would be obtained if the rotor and stator teeth had the same pitch. This specification appears to cover the same ground as British Patent 13904/1915.

888. HIGH FREQUENCY VARIABLE RELUCTANCE ALTERNATORS. M. Osnos. (*L'Elettrotecnica*, 7, pp. 228—229, May 5th, 1920—Abstract.)

Abstract of paper from the *Jahrbuch der drahtlosen Telegraphie*, 13, p. 270, November, 1918, dealing with the Cail-Hermer and Guy alternators.

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* RADIO REVIEW Abstract No. 23, Nov. 1919.

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889. HIGH FREQUENCY ALTERNATOR WINDINGS. E. O. Turner. (*British Patent* 136215, November 14th, 1918. Patent accepted December 15th, 1919. *L'Électricien*, 51, p. 284, July 1st, 1920—Abstract.)

This specification relates to A.C. generators with a large number of field poles and provides for the use of an armature winding in which the pitch differs slightly from the pole pitch. The object of this arrangement is to overcome the distortion of the wave form usually obtained in machines having only one slot in the rotor per pole on the stator. In such machines there is usually no room for the insertion of more slots per pole if space is to be left for the windings themselves. By making the pole pitch on the rotor slightly different to the pole pitch on the stator, the E.M.F. induced in any one conductor is slightly different in phase from the E.M.F. induced in the next similarly disposed conductor of the same phase winding. If necessary some of the slots on the rotor may be left blank in order to obtain this type of winding, so that part only of the rotor periphery is utilised.

890. HIGH FREQUENCY MODULATING APPARATUS. R. A. Heising. (*British Patent* 140807, March 26th, 1920. Convention date, November 14th, 1914. Patent not yet accepted but open to inspection.)

For the modulation of a high frequency current it is proposed to include the plate circuit of a three-electrode valve in series with the output circuit of an amplifier connected to a source of high frequency oscillations. By modulating the potential of the grid of the controlling valve the amplitude of the high frequency current pulses flowing through the plate circuit of this valve may be controlled, and thus the oscillations in the aerial or other apparatus which is coupled to that circuit may likewise be modulated.

891. HIGH FREQUENCY MODULATING APPARATUS. H. J. van der Bijl. (*British Patent* 141732, April 15th, 1920. Convention date, August 1st, 1915. Patent not yet accepted but open to inspection.)

A triode valve used as an amplifier is arranged for modulating the high frequency output oscillations by coupling to its grid circuit both the modulator (microphone or signalling key) and the source of high frequency oscillations. The output circuit of the amplifying valve is coupled to the transmitting aerial circuit. For best results the potential applied to the grid circuit by the signalling current should be from three to ten times as much as that from the high frequency source.

892. GASEOUS TELEPHONE TRANSMITTERS. R. A. Engler. (*Electrical Experimenter*, 7, pp. 1154—1155 and 1200—1202, March, 1920.)

The author describes telephone transmitters suitable for wire or wireless work in which a magnet attached to the diaphragm is used to vary the conductivity of a tube containing ionised gas through which the current to be modulated is passed. The ionisation may be obtained from an auxiliary arc, from a hot filament, by X-rays and by any other well-known method. Various modifications are described including one in which it is suggested that the magnet attached to the transmitting diaphragm may be used to vary the position of the grid wire in a three-electrode tube.

893. TELEPHONE RELAYS. J. B. Pomey. (*Revue Générale de l'Électricité*, 7, pp. 665—669, May 15th, 1920. *Technical Review*, 6, p. 589, July 6th, 1920—Abstract.)

This article describes a number of different arrangements of telephone repeaters dealt with in various French and other patents. Both single-way and two-way repeaters are described.*

894. TELEPHONE RECEIVERS. S. G. Brown. (*British Patent* 134353, November 9th, 1918. Patent accepted November 6th, 1919.)

Special constructional arrangements for telephone receivers are described.

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* See also RADIO REVIEW Abstract No. 515, July, 1920.

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895. TELEPHONE TRANSMITTERS. P. L. Jensen. (*U.S. Patent* 1332973, January 2nd, 1918. Patent granted March 2nd, 1920.)

In conjunction with a microphone transmitter in which the diaphragm is exposed to noise vibrations on both sides, means are provided for supporting the mouthpiece at the correct distance from the speaker's mouth by means of suitably shaped pads and an attachment to speaker's head.*

896. TELEPHONE REPEATERS. B. Gherardi and F. B. Jewett. (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 68—135, March, 1920.)

A reproduction of a paper read before the American Institute of Electrical Engineers. See RADIO REVIEW Abstract No. 228, March, 1920, for abstract.

897. TELEPHONE REPEATERS. M. Latour. (*British Patent* 140506, December 5th, 1918. Convention date, December 5th, 1917. Patent accepted April 1st, 1920.)

Various arrangements of three-electrode valve repeaters for telephone lines are described and formulæ are given for calculating the best arrangements and windings for the coupling transformers.

898. A ONE-TUBE RADIOTELEGRAPH AND RADIOPHONE TRANSMITTER. P. H. Boucheron. (*Electrical Experimenter*, 8, pp. 57 and 107—109, May, 1920.)

Constructional details are given for a transmitting set employing any ordinary receiving type of three-electrode tube.

899. SOME LONG-DISTANCE RADIOTELEPHONY TESTS. R. F. Gowen. (*Electrical Experimenter*, 7, pp. 1281 and 1326, April, 1920.)

Details are given of some long-distance tests made by the de Forest Radio Telephone Company using a 1 kW. three-electrode valve transmitter. A range of 1,500 miles was obtained using less than 300 watts.†

900. A HIGH POWER WIRELESS TELEPHONY INSTALLATION. F. P. Swann. (*Wireless World*, 8, pp. 76—79, May 1st, 1920. *Technical Review*, 6, p. 548, June 22nd, 1920—Abstract.)

See also RADIO REVIEW Abstract No. 901 for further reference to the same apparatus.

901. WIRELESS TELEPHONE PROGRESS. (*Electrician*, 84, pp. 568—570, May 21st, 1920. *Technical Review*, 6, p. 558, July 6th, 1920—Abstract.)

Describes the latest developments of wireless telephone transmitting apparatus by Marconi's Wireless Telegraph Company. A 6 kW. and a 15 kW. set are described and illustrated.‡

902. THE ACTION OF THE WIRELESS TELEPHONE. R. A. Mallett. (*Model Engineer*, 42, pp. 484—485, May 20th; pp. 500—502, May 27th; pp. 536—541, June 10th; pp. 560—562, June 17th; pp. 578—580, June 24th, 1920.)

A brief *résumé* of the principles of operation of the wireless telephone apparatus including descriptions of several leading circuits using three-electrode valves.

903. APPARATUS FOR CONTROLLING ELECTRICAL ENERGY IN SIGNALLING SYSTEMS. C. D. Ehret. (*La T.S.F. Moderne*, 1, pp. 61—62, May, 1920—Abstract.)

See RADIO REVIEW Abstract No. 340, May, 1920.

904. CONSTRUCTION OF A SIMPLE RADIO TELEPHONE. E. S. Rogers. (*Radio Amateur News*, 1, p. 343, January, 1920.)

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* See also RADIO REVIEW Abstract No. 341, May, 1920.

† See also RADIO REVIEW Abstracts Nos. 614 and 618, August, 1920.

‡ See RADIO REVIEW Abstract No. 900, this issue, for further references.

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905. DUPLEX WIRELESS TELEPHONY. General Electric Company, U.S.A. (*British Patent* 141386, October 30th, 1916. Patent accepted April 22nd, 1920.)

Describes an arrangement for duplex wireless telephony using separate aerials for transmission and reception at each station, and with a telephone circuit connected to the two aerials *via* a telephone exchange and a magnetic modulator. Different frequencies are used for transmission and reception.

906. WIRELESS TELEGRAPH STATIONS. H. J. J. M. de R. de Bellescize. (*British Patent* 134497, May 24th, 1919. Convention date, January 22nd, 1919. Patent accepted November 6th, 1919.)

In a duplex or multiplex wireless station using a main transmitting aerial in conjunction with one or more distant receiving aerials it is proposed to link up the receiving sets with the transmitting station direct so that the incoming messages are received at the transmitting station. For this purpose the receiving apparatus may be coupled through some form of repeater to a telephone line connecting the two stations. It is suggested that a convenient repeater for this purpose would be some form of microphone repeater in which the incoming signals after detection influence acoustically a microphone connected to the telephone line between the two stations. By this means the complete receiving apparatus may be enclosed in a metallic box and the acoustic vibrations made to affect the microphone through a perforated or gauze window.

907. SIMULTANEOUS SENDING AND RECEIVING. E. F. W. Alexanderson. (*Génie Civil*, 76, p. 195, February 14th, 1920. *Revue Général de l'Électricité*, 7, p. 132D, April 24th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 75, December, 1919.

908. WIRELESS SIGNALLING SYSTEMS. Siemens and Halske Akt. Ges. (*British Patent* 142846, May 5th, 1920. Convention date, April 24th, 1918. Patent not yet accepted but open to inspection.)

This specification deals with a system of radio signalling in which a definite group frequency is employed distinct from the wave frequency and the signalling or tone frequency, the group frequency being intermediate in value between the other two frequencies. In the case of a C.W. transmitter the term tone frequency would be taken to refer to the time period of the shortest signalling dot and in the case of musical spark telegraphy to refer to the period of the audible tone. In order to secure the maximum effects at the receiver it is desirable that the group frequency and the damping of the circuits at the transmitter and receiver should be such that the oscillations in the transmitting aerial are just able to build up to their maximum amplitude in the period of each group and similarly that the oscillations induced in the receiving circuits are also able to build up to their maximum amplitude during the time period of each group.

The group frequency may be obtained by modulation of the amplitude of the high-frequency oscillations set up in the transmitting aerial by any well-known means. At the receiver the aerial and secondary circuit coupled thereto are tuned to the wave frequency and the resulting oscillations then rectified by means of a suitable detector. The output circuit of this detector is tuned to the group frequency and the damping of the circuit is adjusted so that the oscillations of the group frequency set up therein are just enabled to build up to their maximum amplitude in the duration of the shortest signalling dot used, or during the tone period in the case of musical spark telegraphy. These oscillations of the group frequency may be rectified by a second detector the output of which may either directly influence a telephone receiver or may be transferred to a third circuit tuned to the audible tone frequency in the case of musical spark telegraphy.

It is stated to be preferable that the group frequency be made equal to the geometric mean between the wave frequency and the signal or tone frequency, since the damping factors of all circuits may then be as high as possible with a minimum loss of energy.

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909. ELECTRIC DISCHARGE APPARATUS. H. C. Rentschler. (*British Patent* 139514, February 27th, 1920. Convention date, February 27th, 1919. Patent not yet accepted but open to inspection.)

A special three-electrode valve is described in which the grid is maintained at a positive potential with respect to both the plate and the filament, the plate being at a smaller positive potential with respect to the filament. Argon or a metallic vapour which exhibits the phenomenon of resonance potential is used in the valve. It is stated that the apparatus may be used as a detector, amplifier or frequency doubler, and that its mode of operation depends upon the varying conditions of the impact of the electrons on the gas molecules with the potential applied to the grid.

910. ELECTRIC DISCHARGE APPARATUS. H. C. Rentschler. (*British Patent* 139518, February 27th, 1920. Convention date, February 27th, 1919. Patent not yet accepted but open to inspection.)

An addition to British Patent 139514 (RADIO REVIEW Abstract No. 909) describing a similar three-electrode valve with the positions of the electrodes and the value of the grid and plate voltages adjusted so that the maximum effect due to resonance potential of the gas molecules occurs when the anode current is just beginning to diminish owing to secondary emission of electrons from its surface.

911. ELECTRIC DISCHARGE APPARATUS. P. Schwerin. (*British Patent* 143262, May 14th, 1920. Convention date, November 1st, 1916. Patent not yet accepted but open to inspection.)

For the purpose of maintaining cool the anode of a thermionic valve it may be constructed in the form of a tube through which a cooling liquid such as water or oil may be circulated. The tube may be arranged in the form of a helix in the case of a cylindrical type of valve or in the form of a zig-zag in the case of a flat type of valve. The ends of the tube may be brought out through the seals at the ends of the valve for the purpose both of introducing the cooling liquid and for making connection to the anode.

912. ELECTRIC DISCHARGE APPARATUS. H. W. Weinhart. (*British Patent* 143519, May 17th, 1920. Convention date, November 1st, 1915. Patent not yet accepted but open to inspection.)

An addition to British Patent 143262 * providing for an alternative arrangement for cooling the anode of a triode valve. It is proposed to construct the anode in the form of a cylindrical tube one end of which opens outside the valve and is sealed to the walls of the valve, while the inner end of the tube is closed and a smaller tube is passed up the centre of the main anode tube so that circulating water or oil for cooling purposes may be passed up the central tube returning by the angular space between the two tubes. The grid is wound around the anode tube and insulated from it while the filaments are supported on the outside of the anode and grid by means of suitable glass supports.

913. THE MANUFACTURE OF AMPLIFYING VACUUM TUBES. E. Rüchardt. (*Science Abstracts*, 23B, pp. 170—171, Abstract No. 343, March, 1920—Abstract.)

See RADIO REVIEW Abstract No. 286, April, 1920.

914. VACUUM VALVES. S. Dushman. (*British Patent* 139748, July 30th, 1919. Convention date, March 4th, 1919. Patent not yet accepted but open to inspection.)

A special construction for three-electrode valves is described in which the cylindrical anode is provided with heat radiating fins extending outwards from its outer surface in a radial direction. These fins may also be employed for supporting the anode.†

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* See RADIO REVIEW Abstract No. 911.

† See also RADIO REVIEW Abstract No. 916.

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915. THERMIONIC VALVE APPARATUS. Siemens-Schuckertwerke. (*British Patent* 141706, April 12th, 1920. Convention date, January 27th, 1917. Patent not yet accepted but open to inspection.)

In the apparatus described the cathode is in the form of a cylindrical tube placed inside and concentric with the cylindrical anode and heated by electronic bombardment from a filament placed within it. It is stated that with four amperes through the internal filament, and with a voltage of 630 volts between the filament and the cathode, the cathode tube will be maintained at a temperature of about 2000° C.

916. THERMIONIC VACUUM VALVES. General Electric Company, U.S.A. (*British Patent* 140166, February 10th, 1919. Patent accepted March 25th, 1920.)

A special construction of cylindrical anode is described provided with external projecting strips for attachment to the supports.*

917. IMPROVEMENTS IN THREE-ELECTRODE VACUUM TUBES. J. Erskine-Murray. (*Science Abstracts*, 23B, p. 110, Abstract No. 206, February, 1920—Abstract.)

See RADIO REVIEW Abstract No. 351, May, 1920.

918. NOTES ON THE PHYSICS OF THE THERMIONIC VALVE. T. G. Petersen. (*Wireless World*, 7, pp. 566—572, January; pp. 638—644, February; pp. 686—690, March, 1920. *Technical Review*, 6, p. 342, April 13th, 1920—Abstract.)

The author first summarises the kinetic theories leading up to the emission of electrons from hot metals in a vacuum and thence to the reasons for the use of tungsten filament for such purposes. The effect of the grid is considered in detail by graphical methods showing the potential gradient between the filament and the anode. The effect of altering the grid diameter and mesh is shown by these curves as well as the influence of the distance between the anode and the filament. A summary is given of the methods by which the operating constants—plate current, amplification factor, internal resistance, etc., may be determined from the structural dimensions; and finally various methods of exhaustion are summarised. This last section includes a description of the Langmuir condensation pump and of the method of freeing the electrodes and glass from absorbed gases by electronic bombardment.

919. HARDENING AND SOFTENING OF IONIC TUBES. W. H. Eccles; C. L. Fortescue and C. B. Bryan; B. S. Gossling. (*Technical Review*, 6, p. 301, March 30th, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 103—104, November, 1919; p. 160, December, 1919; and pp. 261—264, February, 1920.

920. EFFECT OF THE POTENTIAL DROP ALONG THE FILAMENT OF A VALVE ON ITS SENSITIVENESS AS A DETECTOR. E. Green. (*Science Abstracts*, 23B, p. 222, Abstract No. 434, April, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 276—278, March, 1920, for original paper.

921. THE OSCILLATING TRIODE. R. C. Clinker; R. Whiddington; W. H. Eccles. (*Radio Review*, 1, pp. 159—160, December, 1919; pp. 211—212, January, 1920.)

922. AN INVESTIGATION OF THE INTERNAL ACTION OF A TRIODE VALVE. W. H. Eccles. (*Science Abstracts*, 23B, p. 171, Abstract No. 344, March, 1920—Abstract.)

See RADIO REVIEW Abstract No. 425, June, 1920.

923. QUANTITATIVE STUDY OF TRIODE GENERATORS WITH THE AID OF OSCILLATION CHARACTERISTICS. H. G. Möller. (*Science Abstracts*, 23B, pp. 110—111, Abstract No. 208, February, 1920—Abstract.)

See RADIO REVIEW Abstract No. 293, April, 1920.

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* See also RADIO REVIEW Abstract No. 914.

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924. TRIODE NOMENCLATURE AND SYMBOLS. L. B. Turner; E. V. Appleton; C. L. Fortescue; A. Press. (*Radio Review*, 1, pp. 314—316, March, 1920; p. 368, April, 1920; pp. 417—418, May, 1920; p. 472, June, 1920.)

925. ON THE INPUT IMPEDANCE OF THE THERMIONIC AMPLIFIER. S. Ballantine. (*Physical Review*, 15, pp. 409—420, May, 1920.)

At low frequencies the input impedance of the three-electrode vacuum tube behaves as a pure capacity. At radio frequencies due to the internal capacity between the grid and plate electrodes, the input impedance resembles the combination of a condenser shunted by a conductance. The effective capacity and conductance of the input circuit are then functions of the load in the plate circuit. An inductive load may give rise to a negative input impedance and consequent feed-back or regenerative effects. These effects may be of especial importance in the design of cascade amplifiers.

For the purpose of the mathematical development the input impedance is defined as the ratio of the impressed E.M.F. to the current in the grid circuit, this current arising partly through the direct effect of the applied E.M.F. and partly through the feed-back effect of the grid-plate capacity of the valve. The input impedance Z_0 may be expressed as $g + j\omega C$ where g and C represent the effective conductance and capacity respectively. Equations are developed for the general case in which the load in the plate circuit consists of an inductance L in series with resistance R. In this case if the inductance is large its self-capacity becomes additive to the plate-filament capacity of the tube if the external resistance in series with it

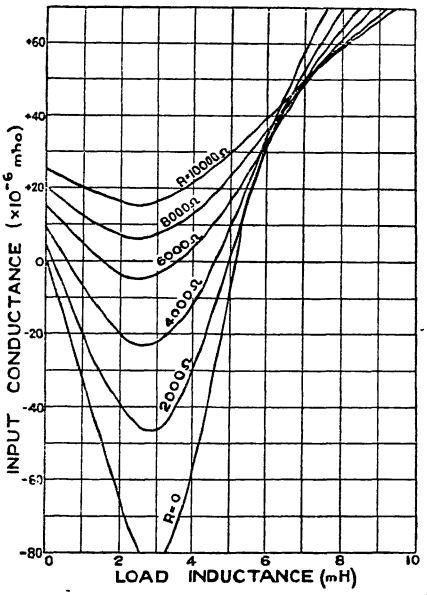

FIG. 3.—Input Conductance Curves for Composite Load, $Z = R + j\omega L$.

$\omega = 3 \times 10^6$; $\lambda = 627$ m.

Values of R are marked on the curves.

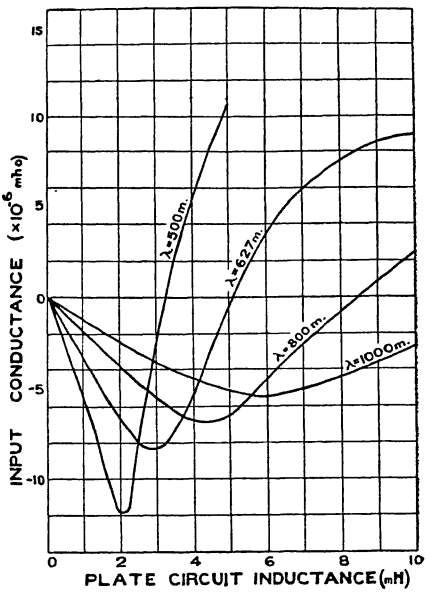

FIG. 4.—Effect of Frequency with Pure Inductance Load.

$R = 0$.

$R_0 = 20{,}000$ ohms; $\mu_0 = 6$; $C_1 = C_2 = C_m = 10\mu\mu$F.

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is negligible, as is generally the case. The effective input conductance and capacity are then shown to be as follows :—

$$g = \frac{\omega^2 C_m R_0[(\omega^2 L^2 + R^2)\{C_m + \mu_0(C_2 + C_m)\} + RR_0C_m - L\mu_0]}{[R + R_0\{1 - \omega^2 L(C_2 + C_m)\}]^2 + \omega^2[L + RR_0(C_2 + C_m)]^2}$$

and

$$C = \frac{\left[\{R + R_0)^2 + \omega^2 L^2\}\{C_1 + C_m(1 + \mu_0)\} - R_0(R + R_0)C_m\mu_0 + \right.}{\left. + \omega^2 R_0^2(C_2 + C_m)\left\{(\omega^2 L^2 + R^2)C_0 - L\left(\frac{C_0}{C_2 + C_m} + C_1 + C_m\right)\right\}\right]}$$
$$[R + R_0\{1 - \omega^2 L(C_2 + C_m)\}]^2 + \omega^2[L + RR_0(C_2 + C_m)]^2$$

where $C_0 = C_1C_m + C_2C_m + C_1C_2$; C_1 = grid-filament capacity; C_m = grid-plate capacity; C_2 = plate-filament capacity; R_0 = the internal plate-filament resistance of the tube, and μ_0 = magnification factor of the tube ($= e_p/e_g$).

The occurrence of the term $\omega^2 C_m$ in the numerator of the expression for g indicates the importance of the regenerative action at high frequencies or short wavelengths. Curves are given in the original showing the values of g and C for various load inductances and resistances. Two typical curves are given in Figs. 3 and 4 and from these the range of regeneration, when the input conductance is negative, can be seen. An important practical deduction is that for any given frequency it is possible to load the plate circuit with such an impedance for the purpose of linking two valves in cascade that the input circuit exhibits no effect other than that of an increase in capacity, and hence a cascade amplifier constructed on these lines would then be perfectly stable.

Two special cases are also considered in the paper in which the load in the plate circuit consists of either pure inductance or pure resistance. This leads to a simplification of the general equations given above. The conditions for maximum regeneration are also investigated and the following equation derived for the value of L required to give the maximum regeneration :—

$$L' = R\,\frac{\omega R_0 C' \pm \sqrt{\omega^2 R_0^2 C_m^2 + \mu_0^2}}{\omega[R_0^2\omega^2(C_2 + C_m)(C' + C_m) - \mu_0]}$$

where $C' = C_m + \mu_0(C_2 + C_m)$.

It is also shown from the equations and curves that if the inductance in the plate circuit is large—such as may arise from a pair of telephones—and has considerable distributed capacity a very considerable loss may be involved owing to the increase in the effective input conductance caused thereby.

926. AMPLIFIERS. M. Latour. (*Science Abstracts*, 23B, p. 67, Abstract No. 137, January, 1920—Abstract. *Electrical World*, 75, p. 1015, May 1st, 1920—Abstract.)
See RADIO REVIEW Abstract No. 291, April, 1920.

927. AMPLITUDE OF THE OSCILLATING CURRENT SET UP BY AUDION GENERATORS. A. Blondel. (*Science Abstracts*, 23B, p. 110, Abstract No. 207, February, 1920—Abstract.)
See RADIO REVIEW Abstract No. 418, June, 1920.

928. THE AUDION AS A CIRCUIT ELEMENT. H. W. Nichols. (*Physical Review*, 13, pp. 404—414, June, 1919.)

The functional equations for the three element valve or audion are used to deduce the actions taking place in any circuit containing the valve. It is assumed that the variations in the plate and grid currents and voltages are small. The equivalent circuits are developed which would replace the valve, and thus avoid the necessity of utilising the complete set of equations for all problems. The importance of the grid-filament and the grid-plate capacities is emphasised by two examples dealing respectively with the input impedance of the audion amplifier and with amplification at high frequencies.

929. COUPLING OF MULTI-STAGE AMPLIFIERS. G. W. O. Howe. (*Science Abstracts*, 23B, p. 223, Abstract No. 435, April, 1920—Abstract.)
See RADIO REVIEW, 1, pp. 279—280, March, 1920, for original paper.

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930. "The Thermionic Valve and its Developments in Radiotelegraphy and Telephony" by J. A. Fleming. B. S. Gossling. (*Radio Review*, 1, pp. 156—159, December, 1919. *Annales des Postes, Télégraphes et Téléphones*, 9, pp. 148—149, March, 1920—Abstract.)
Review of book with the above title.

931. Technical Development of Thermionic Transmitters. L. Kühn. (*Science Abstracts*, 23B, p. 110, Abstract No. 205, February, 1920—Abstract.)
See Radio Review Abstract No. 295, April, 1920.

932. Early Developments of the Three-electrode Tube. H. J. van der Bijl; M. Latour. (*Radio Review*, 1, pp. 467—469, June, 1920.)

933. The Versatile Audion. H. W. Secor. (*Electrical Experimenter*, 7, pp. 1000—1001 and 1080—1083, February, 1920.)
A popular *resumé* of some of the many radio and other uses to which the three-electrode valve may be put.

934. On the Detecting Efficiency of the Thermionic Detector. H. J. van der Bijl. (*Revue Générale de l'Électricité*, 6, pp. 501—502, October 18th, 1919—Abstract.)
See Radio Review Abstract No. 296, April, 1920, for the original paper.

935. Detecting Efficiency of the Thermionic Detector. H. J. van der Bijl. (*Science Abstracts*, 23B, p. 111, Abstract No. 212, February, 1920—Abstract.)
See Radio Review Abstract No. 296, April, 1920.

936. Oscillations obtained by Coupling a Secondary Circuit with a Continuous Wave Valve Oscillator. J. S. Townsend. (*Radio Review*, 1, pp. 369—374, May, 1920. *Technical Review*, 6, p. 506, June 8th, 1920—Abstract. *Science Abstracts*, 23B, p. 326, Abstract No. 642, June 30th, 1920—Abstract.)

937. Determination of Characteristic Curves of Triodes. R. Jaeger. (*Science Abstracts*, 23B, p. 111, Abstract No. 210, February, 1920—Abstract.)
See Radio Review Abstract No. 297, April, 1920.

938. Vacuum Tube Rectifiers. J. Nienhold. (*British Patent* 142870, May 8th, 1920. Convention date, May 15th, 1917. Patent not yet accepted but open to inspection.)
Relates to a vacuum tube rectifier in which the cathode is made of electro-positive material such as potassium or potassium alloy and is of large surface while the anode or anodes have a small surface and are made of electro-negative materials such as copper or constantan. Argon, helium or neon at a pressure of from 0·1 mm. to 20 mm. may be used in the tubes.

939. Radio Compass. P. H. Boucheron. (*Electrical Experimenter*, 7, pp. 906—907 and 949—951, January, 1920.)
Some of the early experimental work of direction finding is referred to together with the subsequent development of the apparatus by the U.S. Navy. In the apparatus described a loop aerial is employed consisting of twelve turns of wire on a frame 6 feet square.* A map is also given of the location of the various D.F. stations in the neighbourhood of New York Harbour†. In conclusion the theory of the apparatus is briefly touched upon.

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* See Radio Review Abstract No. 360, May, 1920, for further description.
† See also Radio Review Abstract No. 203, February, 1920, and No. 710, August, 1920.

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940. THE FESSENDEN PELORUS (WIRELESS COMPASS): A CAUTION AS TO ITS USE. R. A. Fessenden. (*Science Abstracts*, 23B, pp. 164—165, Abstract No. 332, March, 1920—Abstract. *Elektrotechnische Zeitschrift*, 41, p. 420, May 27th, 1920—Abstract.)
See RADIO REVIEW Abstract No. 431, March, 1920.

941. RADIO GUIDES SHIP THROUGH FOG. (*Electrical Experimenter*, 7, p. 781, December, 1919.)
A short note relative to the work of the radio compass stations at New York.

942. WIRELESS DIRECTION FINDING. J. Erskine-Murray and J. Robinson. (*British Patent* 141190, April 10th, 1919. Patent accepted April 15th, 1920. *Engineer*, 129, p. 544, May 21st, 1920—Abstract.)
This relates to an arrangement for receiving signals from a special transmitting station of the "radiophare" type in which signals are successively sent out in various directions of the compass. In the receiving apparatus described the detector is coupled to the aerial circuit through one or other of two variable couplings which may be adjusted until the strength of signals received from two successive transmissions may be made equal. The position of the variable coupling coil then enables a more accurate bearing to be obtained by giving the ratio of the signal strengths for two adjacent compass positions. It is also suggested that the programme of the transmitting station may be varied so that series of pairs of signals are sent out at adjacent compass positions thus enabling a better adjustment of the receiver to be obtained. The comparison of the signal strengths at the receiver may be arranged to be effected automatically in synchronism with the signals from the transmitting station.

943. WIRELESS DIRECTION FINDING. N. P. Hinton. (*La T.S.F. Moderne*, 1, pp. 26—27, April, 1920—Abstract.)
See RADIO REVIEW Abstract No. 359, May, 1920.

944. HOW TO MAKE A DIRECTION FINDER. (*Wireless World*, 8, pp. 244—246, June 26th, 1920; pp. 287—289, July 10th, 1920.)
Constructional details are given of a radiogoniometer for use with a Bellini-Tosi type of aerial.

945. DIRECTIVE WIRELESS SIGNALLING. C. K. Chandler. (*British Patent* 141587, July 25th, 1919. Patent accepted April 22nd, 1920.)
The arrangement described provides for the correction of errors in direction finding on aircraft arising from the currents induced in stay wires or other metal parts of the aeroplane. To effect the correction a fixed coil is mounted in the machine near the rotating D.F. aerials and is connected up through a rotating switch which is mechanically coupled to the rotating aerials so that the circuit of the correcting coil is closed through appropriate condensers to effect the desired correction for all positions of the D.F. aerial.

946. AERIAL ARRANGEMENTS FOR WIRELESS SIGNALLING. F. A. Kolster. (*British Patent* 138318, December 24th, 1919. Convention date, January 30th, 1919. Patent not yet accepted but open to inspection.)
For directional reception a frame aerial A, Fig. 5, is used in series with a tuning condenser C. In order to obtain an asymmetric reception curve one or other terminal of the tuning condenser is connected to earth through a tuning inductance L. The switch S_1 enables this earth connection to be changed over from one terminal to the other so as to reverse the direction of maximum reception. The frame aerial A should be formed with its turns well separated so that it has a large capacity to earth but very small distributed turn-to-turn capacity. The mid-point of the frame coil may be connected to a wire gauze grid B to increase the capacity to earth, or alternatively it may be connected to a separate elevated aerial. The switch S_2 in the diagram serves to connect the detecting valve V either across the coil L for standby reception, or across the tuning condenser C for directional working.

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Alternatively the single frame coil A may be replaced by two coils at right angles to each other or by a toroidal coil with movable connections to the tuning condenser. In this last

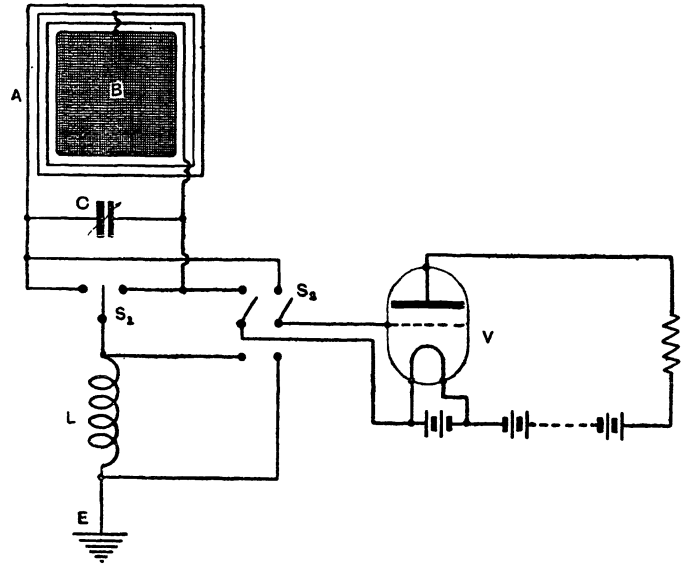

Fig. 5.

case the direction of reception when the movable connections have been adjusted to give maximum signal strength is given by the direction at right angles to the line bisecting the angle between the two movable connections.

947. On the Goniometric Functions Applicable to Directive Aerials. A. E. Blondel. (*Science Abstracts*, 23B, pp. 64—65, Abstract No. 131, January, 1920—Abstract.)
See Radio Review, 1, pp. 1—10, 58—60, 110—123, October, November, and December, 1919. Also Radio Review Abstract No. 362, May, 1920.

948. Wireless Direction Finding. F. E. Smith. (*Radio Review*, 1, pp. 415—417, May, 1920. *Technical Review*, 6, p. 506, June 8th, 1920—Abstract.)

949. The Height of the Aurora Borealis as Determined at the Haldde Observatory, Norway. L. Vegard and O. Krognes. (*Journal of the Franklin Institute*, 189, p. 674, May, 1920.)
A large number of measurements are summarised. These all indicate an average height of 108·2 kilometres for the lower boundary of auroræ. The observations centre particularly round two heights of 100 and 106 kilometres respectively.

950. Propagation of Electromagnetic Waves over a Plane Conducting Surface. H. Weyl. (*Elektrotechnische Zeitschrift*, 41, p. 400, May 20th, 1920—Abstract.)
See Radio Review Abstract No. 433, June, 1920.

951. The Transmission of Electromagnetic Waves about the Earth. J. Erskine-Murray. (*Wireless World*, 7, pp. 651—664, February, 1920. *Technical Review*, 6, p. 263, March 16th, 1920—Abstract. *Telegraphen- und Fernsprech-Technik*, 9, p. 65, July, 1920—Abstract.)
See Radio Review, 1, pp. 237—239, February, 1920, for abstract.

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952. ON THE PROPAGATION OF ELECTROMAGNETIC WAVES AROUND THE EARTH. B. van der Pol. (*L'Elettrotecnica*, 7, pp. 269—270, May 25th, 1920—Abstract.)
See RADIO REVIEW Abstracts No. 48, November, 1919, and No. 513, July, 1920.

953. DETECTOR FOR WIRELESS TELEGRAPHY. J. Nienhold. (*German Patent* 304373, August 4th, 1917. Patent granted October 17th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 509—510 June, 1920—Abstract.)

A detecting circuit (see Fig. 6) in which the valve tube which contains a rare gas or a mixture of rare gases is provided with three electrodes. The cathode K is coated with an alkali metal and a constant glow discharge is maintained between it and the sieve-like anode m. Rectification is obtained by utilising the asymmetrical electrical properties of the space between m and a.

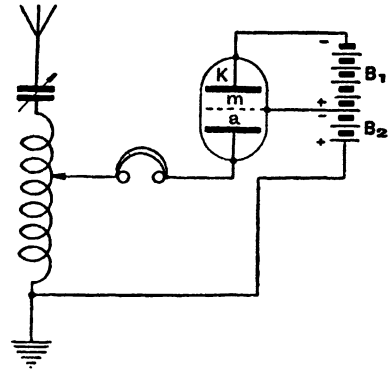

FIG. 6.

954. POSSIBLE ETHER STRUCTURE. O. J. Lodge. (*Philosophical Magazine*, 39, pp. 170—174, February, 1920. *Science Abstracts* 23A, p. 194, Abstract No. 505, April, 1920—Abstract.)

955. THE STOKES-PLANCK ETHER. L. Silberstein. (*Philosophical Magazine*, 39, pp. 161—170, February, 1920. *Science Abstracts*, 23A, pp. 194—195, Abstract No. 506, April, 1920—Abstract.)

956. VARIATION IN DIRECTION OF PROPAGATION OF LONG ELECTROMAGNETIC WAVES. A. H. Taylor. (*Science Abstracts*, 23B, p. 163, Abstract No. 331, March, 1920—Abstract. *Electrical World*, 76, p. 137, July 17th, 1920—Abstract.)
See RADIO REVIEW Abstract No. 430, June, 1920.

957. RADIOTELEGRAPHY IN THE ALPS. (*Engineering*, 109, p. 753, June 4th, 1920.)

A brief note referring to a series of experiments conducted in Switzerland last year between forty radio stations distributed over the country to determine the influences of topographical features on the range of signalling. The wavelengths used varied between 600 and 2,100 metres. Extensive plains, valleys, lakes and water courses were found to increase the range, while high mountain chains and expanses of firm grainy snow diminished the range. Best signals were obtained with a wavelength between 900 and 1,800 metres.

958. MEASUREMENT OF THE STRENGTH OF THE ELECTROMAGNETIC FIELD OF TRANSOCEAN WIRELESS SIGNALS. G. Vallauri. (*L'Elettrotecnica*, 7, pp. 298—300, June 15th, 1920.)
See editorial article, pp. 652—655 of this issue, where the paper is discussed.

959. ON THE QUANTITATIVE DETERMINATION OF ELECTROMAGNETIC RADIATION FIELD STRENGTH IN WIRELESS TELEGRAPHY. H. R. von Traubenberg. (*Science Abstracts*, 23B, p. 163, Abstract No. 330, March, 1920—Abstract. *Electrical World*, 75, p. 1437, July 19th, 1920—Abstract.)
See RADIO REVIEW Abstract No. 303, April, 1920.

960. REFRACTION OF ELECTRIC WAVES. T. L. Eckersley. (*Radio Review*, 1, pp. 421—428, June, 1920.)

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961. HARMONICS IN C.W. TRANSMISSION. L. A. T. Broadwood. (*Wireless World*, 8, pp. 82—91, May 1st, 1920; pp. 125—131, May 15th, 1920. *Technical Review*, 6, p. 548, June 22nd, and p. 590, July 6th, 1920—Abstract. *Science Abstracts*, 23B, p. 323, Abstract No. 637, June 30th, 1920—Abstract.)

Paper read before the Wireless Society of London. For abstract see RADIO REVIEW, 1, p. 385, May, 1920. The full paper and discussion are given in the *Wireless World*, above reference.

962. RECEIVING APPARATUS FOR WIRELESS TELEGRAPHY AND TELEPHONY. C. Bardeloni. (*British Patent* 141185, April 3rd, 1919. Convention date, October 3rd, 1916. Patent accepted April 15th, 1920.)

This specification provides for the combination of a crystal detector such as carborundum with a thermionic valve. Various modifications are described in which the crystal may be connected in shunt to the tuned secondary circuit of the receiver and with the grid filament circuit of the valve, or it may be connected in series with the grid circuit between the tuned secondary circuit of the receiver and the filament of the valve. Other modifications show the addition of a variable voltage from a potentiometer between the crystal and the grid of the valve.

963. NOTES ON THE DESIGN AND CONSTRUCTION OF VACUUM TUBE AMPLIFIERS. J. Scott-Taggart. (*Wireless World*, 7, pp. 440—444; pp. 505—508; pp. 671—673; pp. 701—704; November, December, February and March, 1920. *Technical Review*, 6, p. 86, January 20th; p. 301, March 30th, 1920—Abstract. *Telegraphen- und Fernsprech-Technik*, 9, pp. 34—35, May, 1920—Abstract.)

This article is divided into three parts dealing respectively with low frequency amplifiers, detector amplifiers and resistance amplifiers. In the first constructional details are given of a suitable inter-valve transformer and a set of diagrams of the arrangements for various stages of amplification. In the second part the arrangement of the amplifier when one of the valves is provided with a grid condenser and leak for detection purposes is set out in detail, together with particulars of the Marconi type 55 seven-valve amplifiers, and the use of a multi-stage amplifier with the circuits of each coupling transformer tuned to the oscillating frequency to increase the selectivity. In the third section resistance capacity coupling is described and its modification using a choke coil to replace the resistance.

964. AN AMPLIFIER EMPLOYING THERMIONIC INTER-VALVE RESISTANCE COUPLINGS. J. Scott-Taggart. (*Electrical Review*, 86, pp. 549—550, April 30th, 1920. *Science Abstracts*, 23B, p. 325, Abstract No. 640, June 30th, 1920—Abstract.)

The article describes a multi-stage amplifier of the resistance—capacity coupled type in which the usual anode resistances are replaced by two-electrode valves. This arrangement provides a convenient means for adjusting the value of the anode resistances by varying the filament heating currents of the two-electrode valves. It is also stated that a certain degree of limiter action may be obtained by choosing suitable values for the filament currents for the two-electrode valves.

965. THERMIONIC VALVE AMPLIFIERS. L. B. Turner. (*British Patent* 139867, February 17th, 1919. Patent accepted March 18th, 1920.)

This specification deals with the coupling of two valves by resistances in the manner described in the RADIO REVIEW by the same author.*

966. THE KALLIROTRON, AN APERIODIC NEGATIVE-RESISTANCE TRIODE COMBINATION. L. B. Turner. (*Radio Review*, 1, pp. 317—329, April, 1920. *Technical Review*, 6, p. 424, May 11th, 1920—Abstract. *Science Abstracts*, 23B, p. 277, Abstract No. 545, May 31st, 1920—Abstract.)

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* "The Kallirotron," L. B. Turner (RADIO REVIEW, 1, pp. 317—329, April, 1920).

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967. THE KALLIROTRON, AN APERIODIC NEGATIVE-RESISTANCE TRIODE COMBINATION. G. B. Ehrenborg; L. B. Turner; M. Latour. (*Radio Review*, 1, pp. 469—472, June, 1920, also pp. 523—524, July, 1920.)
Correspondence relative to the paper by L. B. Turner with the above title.*

968. ON BLONDEL'S AND TOULY'S NEW ARRANGEMENTS OF POTENTIOMETRIC AMPLIFIERS. A. Blondel and M. Touly. (*Science Abstracts*, 23B, p. 88, Abstract No. 166, February, 1920—Abstract.)
See RADIO REVIEW Abstracts Nos. 236 and 237, March, 1920.

969. A NON-RADIATING WIRELESS RECEIVING CIRCUIT FOR THE RECEPTION OF DAMPED AND UNDAMPED WAVES. J. Scott-Taggart. (*Science Abstracts*, 23B, pp. 168—170, Abstract No. 340, March, 1920—Abstract. *Revue Générale de l'Électricité*, 7, p. 133D, April 24th, 1920—Abstract.)
See RADIO REVIEW Abstract No. 170, January, 1920.

970. HETERODYNE RECEPTION. H. Salinger. (*Science Abstracts*, 23B, pp. 109—110, Abstract No. 204, February, 1920—Abstract.)
See RADIO REVIEW Abstract No. 370, May, 1920.

971. RECEIVERS FOR WIRELESS TELEGRAPHY. C. S. Franklin. (*Science Abstracts*, 23B, pp. 166—167, Abstract No. 336, March, 1920—Abstract.)
See RADIO REVIEW Abstract No. 375, May, 1920.

972. ON THE MEASUREMENT OF THE FREQUENCY OF ACOUSTIC AND ELECTRIC OSCILLATIONS BY A BEAT METHOD. R. Weller. (*Science Abstracts*, 23A, p. 234, Abstract No. 596, April, 1920—Abstract.)
See RADIO REVIEW Abstract No. 308, April, 1920.

973. THE REPRODUCTION OF SPEECH BY GALENA WITH UNDAMPED WAVES. Mlle. P. Collet. (*Comptes Rendus*, 170, pp. 1378—1380, June 7th, 1920.)
Some experiments on the acoustic effects of galena crystals are dealt with in this note. For the purposes of these experiments a platinum point attached to the membrane of a phonographic reproducer was mounted so as to rest on the galena crystal. The valve transmitter generating undamped waves was coupled to a circuit containing the galena contact, which latter circuit also included either an interrupter or a microphone transmitter. It was found that the interruptions of the circuit from the speech impressed on it by the microphone transmitter were faithfully reproduced by the diaphragm attached to the galena. Heterodyne phenomena were also evidenced when the galena was coupled to two transmitters operating at different frequencies. The phenomena appear to have a thermal origin.

974. ON TWO TYPES OF CURRENT RECTIFICATION BY GALENA. Mlle. P. Collet. (*Comptes Rendus*, 170, pp. 1489—1491, June 21st, 1920.)
As a result of experiments on rectification of alternating currents and oscillations by galena contacts, the author distinguishes two types of rectification; (1) brought into play when the applied energy is small and (2) when the input power is large. The first case corresponds to that of ordinary wireless reception and the phenomena shown agree with those customarily associated with this detector when used in wireless receivers. It was found that the rectified current was always in one direction for the sensitive points and flowed from the crystal to the metallic point. The output of continuous (rectified) current was found to bear no very definite relation to the input energy, but in the case of the second type of rectification where the input was larger it was found that all points, whether "sensitive" or not in the usual meaning of the term, gave a rectified current in the reverse direction to that given by the ordinary sensitive points working with feeble oscillations. This second type of rectification was in the opposite direction to the first and the sensitive spots on the crystal showed rectification first in one direction, subsequently falling to zero and then in the other direction as the input energy was steadily increased. This phenomenon explains the observation that such crystals

* RADIO REVIEW, 1, pp. 317—329, April, 1920.

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working at their most sensitive points are not such good rectifiers for strong signals as for weaker ones.

975. THE RECTIFYING ACTION OF CRYSTAL DETECTORS. M. J. Huizinga. (*Physikalische Zeitschrift*, 21, pp. 91—96, February 15th, 1920. *Elektrotechnische Zeitschrift*, 41, p. 573, July 22nd, 1920—Abstract.)

A description of experiments to support the view that the rectification is due to electrolysis. On passing 1 milliampere between a platinum point and molybdenum sulphide a drop of liquid forms at the point; with the point negative the liquid is blue and an analysis gives MoO_2, 4 MoO_3, 6 H_2O, with the point positive the resistance is much higher, the liquid is brown and gives MoS_2 and MoS_3. Pyrites and many other minerals gave somewhat similar results, although in some cases no liquid is apparent, due to its evaporation as soon as it is produced. The rectification takes place without any apparent decomposition, however, in a vacuum, in hydrogen or under paraffin. The author gives a number of characteristic curves and comes to the conclusion that the rectification is in all cases due to electrolytic action and to the different polarisation potentials in the two directions. The electrolytic action takes place in an adhering gas or moisture film. The actual resistance of such detectors is much less than is usually assumed and is usually less than 100 ohms.

976. THERMIONIC VALVES—A WIRELESS BELL CALL. (*Times Engineering Supplement*, No. 548, p. 207, June, 1920.)

A description is given of the Fleming five-electrode valve which is designed particularly for use as a relay for calling up a wireless receiving station.*

977. THERMIONIC VALVE RELAYS. R. Whiddington. (*British Patent* 141900, April 15th, 1919. Patent accepted April 29th, 1920.)

In the use of a triode valve as a trigger relay in which the received impulse triggers off the valve oscillations, it has previously been customary to restore the circuits to their normal state by mechanically interrupting one of the oscillatory circuits.† It is now proposed to overcome this complication by inserting in one of the oscillatory circuits a resistance, such as an incandescent lamp having a positive resistance-temperature coefficient. The rise in the resistance of the lamp when oscillations start is then sufficient to quench them out again as soon as the received impulse ceases.

978. A NEW AMPLIFIER. F. Marin. (*L'Électricien*, 49, pp. 132—134, September 30th, 1919. *Science Abstracts*, 23B, pp. 67—68, Abstract No. 138, January, 1920—Abstract.)

An electromagnetically operated microphonic relay amplifier is described for use in radio reception. The apparatus includes an electromagnet which is joined in circuit in place of the usual telephones, with a reed fixed near the coil of the magnet. The reed carries a small carbon block which forms the microphonic contact with a small point of carbon.

See also RADIO REVIEW Abstract No. 169, January, 1920.

979. WIRELESS EMERGENCY CALLING DEVICE FOR SHIPS. (*Elektrotechnische Zeitschrift*, 41, p. 456, June 10th, 1920.)

In view of the newspaper reports of the Marconi automatic calling device ‡ it is pointed out that the Telefunken Company have been developing such a device since 1916. It consists of an automatic sender and an accurately tuned relay receiving device which operates an alarm.

980. RECORDING OSCILLOGRAPHS AND AMPLIFIERS OF EXTREMELY LOW FREQUENCY: THEIR APPLICATION TO THE RECORDING OF RADIOTELEGRAPHIC SIGNALS. H. Abraham and E. Bloch. (*Technical Review*, 6, p. 341, April 13th, 1920—Abstract. *Science Abstracts*, 23B, p. 277, Abstract No. 546, May 31st, 1920—Abstract. *Electrical World*, 75, p. 1325, June 5th, 1920.)

See RADIO REVIEW Abstract No. 439, June, 1920.

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* See RADIO REVIEW Abstract No. 805, September, 1920.

† See RADIO REVIEW Abstract No. 196, February, 1920, and No. 688, August, 1920.

‡ See RADIO REVIEW Abstract No. 551, July, 1920.

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981. WIRELESS RECEIVING SYSTEMS. E. F. W. Alexanderson. (*British Patent* 142074, December 1st, 1919. Convention date, April 18th, 1919. Patent not yet accepted but open to inspection.)

This specification deals with the use of a loop aerial receiver in which the loop functions both as a closed circuit aerial and as an open elevated aerial by reason of its capacity to earth.* In order to secure effective balancing of the currents set up in these two circuits, phase adjusting arrangements of the type previously described by the same author † are included in each circuit. The movable coils of the phase adjuster are joined in series and then finally coupled to the detecting valve or other receiver.

982. WIRELESS RECEIVING APPARATUS. C. P. Ryan. (*British Patent* 141269, August 28th, 1919. Patent accepted April 15th, 1920.)

In order to increase the selectivity of a receiver and to eliminate the effects of atmospherics and undesired transmissions the receiving telephone is placed opposite the end of a resonating tube to which is attached a microphone transmitter coupled to a vibrating relay. This last is connected to a second relay for operating a Morse inker or other recording apparatus. The resonant tube may be tuned to the acoustic frequency of the signals by opening or closing perforations along its length.

983. THE RECEPTION OF WAVES OF VERY HIGH FREQUENCIES. E. H. Armstrong. (*British Patent* 137271, July 9th, 1919. Convention date, December 30th, 1918. Patent not yet accepted but open to inspection.)

In a receiver for waves of very high frequencies the incoming oscillations are first heterodyned to a supersonic frequency, which may be of the order of a million per second. These supersonic beat currents are then amplified and subsequently detected in any known manner as for example by a second heterodyne to give beats of audible frequency. Alternatively the second heterodyne may produce beats of a lower supersonic frequency which may again be amplified before the final detection. The method is said to reduce interference from atmospherics.

984. LONG WAVE RECEPTION AND THE ELIMINATION OF STRAYS ON GROUND WIRES. A. H. Taylor. (*Science Abstracts*, 23B, pp. 167—168, Abstract No. 338, March, 1920—Abstract.)

See RADIO REVIEW Abstract No. 313, April, 1920.

985. LONG WAVES AND STRAYS ON ROGERS ANTENNÆ. A. H. Taylor. (*Electrical Experimenter*, 8, pp. 58—59 and 100—101, May, 1920.)

Paper read before the Institute of Radio Engineers. See RADIO REVIEW Abstract No. 313, April, 1920, for abstract.

986. LOCATING SUBMARINES BY AUDION SIPHONING. E. T. Jones. (*Electrical Experimenter*, 7, p. 782, December, 1919.)

By the term "siphoning" the author apparently refers to re-radiation from the receiving aerial arising from the heterodyning oscillations. The possibility of locating submerged submarines by detecting such radiation from their receiving apparatus by means of a suitable D.F. apparatus is referred to. Experiments are quoted in which a receiving set was enabled to hear a distant station, which it was normally unable to do, when a large antenna in the neighbourhood was picking up those signals with a heterodyne receiver, the radiation from the heterodyne apparently also conveying the received signal with it to the second receiving station. It is stated that experiments have also shown that at the second receiver a large proportion of the atmospheric interference heard in the main receiver was eliminated, and the author therefore suggests that useful results might be obtained by including a small frame

* Compare RADIO REVIEW Abstract No. 75, Fig. 6, December, 1919, and Abstract No. 525, July, 1920.

† See RADIO REVIEW Abstract No. 75, Fig. 4, December, 1919.

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aerial in series with the secondary tuned circuits of the main receiver so that the radiation from those circuits, and from the heterodyne receiver coupled thereto, might be picked up on a second receiver using a frame aerial. Some considerable distance may separate the two receivers.

987. THERMIONIC AMPLIFIERS. H. D. Arnold. (*British Patent* 141040, March 29th, 1920. Convention date, January 5th, 1919. Patent not yet accepted but open to inspection.)

The arrangement described is a filter circuit for the elimination of disturbing impulses, atmospherics, etc. It depends upon the fact that a shock impulse acting upon a resonant circuit which has considerable damping sets up in it oscillations of a different frequency from the sustained waves to which the circuit is resonant. One arrangement is indicated in Fig. 7.

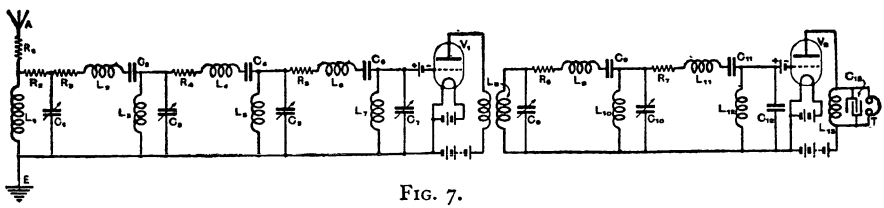

FIG. 7.

In this diagram damping resistances R_1 R_2 R_3 are shown inserted in series with various resonant circuits which are tuned to the incoming wave, the circuits R_3 L_2 C_2; R_4 L_4 C_4; R_5 L_6 C_6, etc., being tuned to this signal frequency so that the undesired impulses are filtered out before reaching the amplifying valve V_1. The amplified currents are then passed through L_8 C_8 and a second series of filtering circuits R_6 L_9 C_9; L_{10} C_{10}; R_7 L_{11} C_{11}, etc., to the detecting valve V_2 and the receiving telephones T. Alternatively if desired an amplifying valve may be placed between each unit of the filtering circuits, that is to say such a valve may replace L_3 C_3; L_5 C_5, etc., so that there is a single resonant filtering circuit only between each valve.

988. THE UNI-CONTROL RECEIVER. R. E. Thompson. (*Science Abstracts*, 23B, p. 70, Abstract No. 141, January, 1920—Abstract.)

See RADIO REVIEW Abstract No. 442, June, 1920.

989. RECEIVING CIRCUITS. H. J. J. M. de Bellescize. (*La T.S.F. Moderne*, 1, pp. 24—25, April, 1920—Abstract.)

See RADIO REVIEW Abstract No. 244, March, 1920.

990. ELECTRIC RELAYS. M. Latour. (*British Patent* 138383, October 19th, 1918. Convention date, October 4th, 1917. Patent accepted February 12th, 1920.)

Provision is made for indicating the failure of the filament of a vacuum tube amplifier by means of a relay having a winding in series with the filament and a shunt winding connected in parallel with it.

991. RECEIVING APPARATUS. Marconi's Wireless Telegraph Company, Limited. (*French Patent* 501493, July 8th, 1919. Published April 15th, 1920.)

The specification describes improvements in receivers for wireless telegraphy which are specially adapted for short wavelengths. For further particulars, see British Patent 134246.*

* RADIO REVIEW Abstract No. 375, May, 1920.

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992. RECEIVING APPARATUS. E. H. Armstrong. (*French Patent* 501511, December 30th, 1918. Published April 16th, 1920.)

The specification describes a method of receiving very high-frequency oscillations. For particulars, see British Patent 137271.*

993. IMPROVEMENTS IN APPARATUS FOR RECEIVING RADIO SIGNALS. R. A. Weagant. (*British Patent* 138586, May 22nd, 1919. Convention date, February 7th, 1919. Patent not yet accepted but open to inspection.)

The subject matter of this patent was described in the article referred to in RADIO REVIEW Abstract No. 18 of October, 1919. See also RADIO REVIEW Abstracts Nos. 62, November, 1919, 312, April, 1920, and 440, June, 1920, where further references are given to descriptions of similar apparatus.

994. POSSIBILITIES OF CONCEALED RECEIVING SYSTEMS. A. H. Taylor. (*L'Elettrotecnica*, 7, pp. 229—230, May 5th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 41, November, 1919.

995. AERIALS, THEIR FORMS AND USES. P. R. Coursey. (*Wireless World*, 8, pp. 109—112, May 15th, 1920. *Technical Review*, 6, p. 589, July 6th, 1920—Abstract.)

A *resumé* of the various types and forms of aerials including some of the advantages of frame aerials for reception purposes.

996. FRAME AERIALS FOR RECEPTION. E. Blake. (*Wireless World*, 8, pp. 152—155, May 29th; pp. 184—188, June 12th, 1920.)

The article reviews the mode of operation of the frame aerial for reception purposes and the leading features in its design for any particular conditions. The latter section follows in a general outline the method developed by A. S. Blatterman.† In conclusion the article deals with some constructional details of a frame aerial suitable for experimental work.

997. AERIAL ARRANGEMENTS FOR WIRELESS RECEPTION. R. A. Weagant. (*British Patent* 138588, August 6th, 1919. Convention date, February 7th, 1919. Patent not yet accepted but open to inspection.)

Further arrangements are described in this specification for minimising the effects of atmospheric interference in wireless reception (see RADIO REVIEW Abstract No. 993). The particular arrangement specified comprises the combination of a vertical non-directive aerial with one or more frame or horizontal directive aerials to that the currents induced by the atmospherics may be cancelled out while the signal current remains. The coupling between the non-directive and directive aerials may be in one direction or the other as most effective for eliminating the atmospherics, or alternatively one of the directive aerials may be rotated to give the best results. In a modification the directive aerials (crossed frames, or crossed horizontal aerials) may be connected to earth through a tuning inductance so that they act both as directive aerials and as elevated non-directive aerials. Compare also RADIO REVIEW Abstract No. 946 in this issue.

998. THE RELATIVE ADVANTAGES OF ELEVATED ANTENNÆ, LOOP AERIALS AND UNDERGROUND WIRES FOR THE RECEPTION OF RADIO-SIGNALS. G. W. O. Howe. (*Radio Review*, 1, pp. 175—178, January, 1920.)

999. RADIOTELEPHONY AND THE AEROPLANE. W. O. Mundt. (*Electrical Experimenter*, 7, pp. 1030 and 1088—1089, February, 1920.)

The author deals with various patterns of aerial that have been employed on aeroplanes. The directional effects of the different arrangements are also considered.

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* RADIO REVIEW Abstract No. 983 in this issue.

† See RADIO REVIEW Abstract No. 144, January, 1920.

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1000. Submarine's Underwater Radio. (*Electrical Experimenter*, 7, pp. 661 and 707, November, 1919.)

Reference is made to some tests between an aeroplane and a submerged submarine carried out by the United States Navy, and particulars are given as to the loop aerial arrangement used on the submarine. A three-stage valve amplifier is used for receiving and a 1 kW. quenched spark for transmission from the submarine. A 0·0005 microfarad condenser is joined in series with the loop.

See also Radio Review Abstract No. 452, June, 1920.

1001. Talking through the Trees. G. O. Squier. (*Technical Review*, 6, p. 263, March 16th, 1920—Abstract.)

See Radio Review Abstract No. 317, April, 1920.

1002. Stationary Waves on Wires. P. R. Coursey. (*Wireless World*, 8, pp. 127—129, June 26th, 1920.)

The arrangements for setting up stationary waves on a long helix are described together with some of their applications.

1003. The Calculation of Loads in Guy Ropes for Masts or Towers. C. T. G. Hooper. (*Science Abstracts*, 23B, p. 112, Abstract No. 213, February, 1920—Abstract.)

See Radio Review, 1, pp. 161—173, January, 1920, for the original article.

1004. Some Wireless Wonders. A. A. Campbell Swinton. (*Wireless World*, 8, pp. 47—57, April 17th, 1920. *Technical Review*, 6, p. 459, June 22nd, 1920—Abstract.)

Presidential address delivered to the Wireless Society of London on February 27th, 1920.

With a few introductory remarks the author briefly reviewed the method of operation of a triode valve and valve amplifying arrangements used with frame aerials for the reception of wireless telegraph and telephone messages. Six oscillograms of the wave form of speech sounds are included, together with a description of the arrangement used at the meeting for the reception and recording of messages from the Eiffel Tower and other large wireless stations. Valve amplifiers were used throughout with a special low frequency amplifier for the final stage which operated a siphon recorder.

1005. Wireless and the Press—The *Daily Mail's* Wireless Station. (*Wireless World*, 8, pp. 222—224, June 26th, 1920.)

A brief illustrated description of the installation at the *Daily Mail* office. A 48-turn frame aerial is employed in conjunction with a seven-valve receiving amplifier.

1006. Wireless Railway Signalling. H. Gewecke. (*Telefunken Zeitung*, 4, No. 20, pp. 56—60, May, 1920.)

A brief description of a system for automatically operating on a locomotive apparatus controlled by wireless signals.

1007. Recent Progress in Wireless Telegraphy. J. O. G. Cann. (*Journal of the Engineering Institute of Canada*, 3, pp. 239—243, May, 1920.)

This paper gives a very brief *resumé* of wireless development under the following heads :—

Historical, giving the leading points in the development from 1867 onwards ; spark system ; arc system, including illustrations of 125 kW. arc installation at Newcastle (Canada) ; the dynamic method (H.F. Alternator) ; the thermionic valve method ; direction finding ; static elimination, including a brief reference to Weagant's receiving aerials ; high speed transmission.

1008. The Wireless Telegraph Apparatus of the German Army. A. Salomon. (*Science Abstracts*, 23B, p. 171, Abstract No. 344, March, 1920—Abstract.)

See Radio Review Abstract No. 447, June, 1920.

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1009. MODERN AMERICAN RADIO APPARATUS. (*Electrical Experimenter*, 7, pp. 779 and 828—829, December, 1919.)
A short general illustrated article briefly describing some of the wartime developments made by the General Electric Company, U.S.A.*

1010. NAUEN RADIO OPENED AGAIN. (*Electrical Experimenter*, 7, p. 662, November, 1919.)
Refers to some of the changes made in the Nauen station during the war. Illustrations of the aerial system and of some of the radio plant are included.

1011. A TWO-STAGE AMPLIFIER. (*Everyday Engineering Magazine*, 9, p. 153, May, 1920.)
An illustrated description of an instrument manufactured by the Wireless Improvement Company.

1012. A FORM OF INDUCTIONLESS HIGH RESISTANCE. N. W. McLachlan. (*Radio Review*, 1, pp. 429—431, June, 1920. *Technical Review*, 6, p. 659, August 3rd, 1920—Abstract.)

1013. THE IMPORTANCE OF THE NAUEN STATION DURING THE WAR. H. Schlee. (*Telefunken Zeitung*, 3, No. 17, pp. 61—64, August, 1919.)
A well-illustrated descriptive article.

1014. NEW MARCONI WIRELESS CALL SIGNAL DEVICE. (*Elektrotechnische Zeitschrift*, 41, p. 358, May 6th, 1920—Abstract. Also, *Electrical Experimenter*, 7, p. 1283, April, 1920—Abstract. *Scientific American*, 122, p. 697, June 26th, 1920—Abstract.)
See RADIO REVIEW, 1, p. 293, March, 1920, and also Abstract No. 551, July, 1920.

1015. WIRELESS SOCIETY OF LONDON'S EXHIBITION OF APPARATUS. (*Wireless World*, 7, pp. 517—530, December, 1919.)
Illustrated descriptions are given amongst others of the following apparatus :—
R.A.F. Wireless Telephone Set; R.A.F. Direction Finding Apparatus with Amplifier; Scott-Taggart—Ediswan Small Power Full-Wave Rectifying Valve; Scott Taggart's Continuous Wave Transmitting Valve; Two- and Three-Valve Amplifiers and a Valve Relay constructed by H. Burberry; Modern Marconi D.F. Apparatus; Leslie Miller's Portable Quenched Spark Transmitter; F. Read's Crystal and Valve Receivers; and a Frame Aerial and Seven-Valve Amplifier used by Mr. Campbell Swinton.

1016. A SENSITIVE TELEGRAPH RECEIVER. W. E. Peirce. (*Telegraph and Telephone Age*, 38, p. 286, May 16th, 1920.)
A short note *re* a new receiver applicable for radio work, in which the diaphragm is arranged to operate an ordinary telegraph sounder or tape recorder.

1017. SELECTIVE WIRELESS CONTROL. E. L. Deeter. (*Electrical Experimenter*, 7, pp. 1284 and 1344, April, 1920.)
A receiving arrangement is described using either a coherer or a two-stage amplifier and relay to control the distant apparatus.

1018. THE WIRELESS HOUND. (*Scientific American*, 122, p. 601, May 29th, 1920. *English Mechanic*, 111, p. 244, June 18th, 1920. *Wireless World*, 8, p. 351, July 24th, 1920—Abstract.)
A short illustrated description of a small vehicle controlled by radio.

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* See also RADIO REVIEW Abstract No. 27, November, 1919.

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1019. INVISIBLE OPTIC TELEGRAPHY BY INFRA-RED RAYS. H. de Gallaix. (*Electrical Experimenter*, 7, pp. 1126—1127 and 1214—1215, March, 1920.)

The development of an apparatus used during the war for telegraphic signalling by infra-red rays is described in this article. At the transmitter a small searchlight was used which contained an electric incandescent or an arc lamp as the light source. The front of the searchlight was fitted with a special glass containing manganese salts which while allowing the infra-red rays to pass was practically opaque to ordinary visible light. At the receiver the beam was concentrated by means of an ordinary type of parabolic searchlight mirror on to an endless paper strip which was driven round by clockwork so that it passed through the focus of the mirror. The paper band was sensitised by a special material containing zinc-sulphate. The effect of the infra-red light caused the paper to turn black and the incoming signals were thus read directly from the moving tape. In its path the paper tape was passed through a second vessel in which it was subjected to blue light from a lamp. This had the effect of obliterating the black marks made by the infra-red rays and of rendering the paper ready for the receipt of fresh messages. Using searchlight mirrors one foot in diameter transmission has been achieved over about half-a-mile. Larger distances may be covered with a more powerful light source.

1020. SELENIUM AND SOME OF ITS USES. P. R. Coursey. (*Wireless World*, 8, pp. 145—149, May 29th, 1920.)

Some of the chemical properties of selenium are passed in review and its applications to photometry, light telegraphy and telephony, control of mechanism by light rays, the optiphone and for recording and reproducing sound waves are dealt with in turn.

1021. EARTH CURRENT TELEGRAPHY. N. Jouaust. (*Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 131, pp. 408—415, November—December, 1919. *Revue Scientifique*, 58, p. 307, May 22nd, 1920—Abstract.)

The principle of the methods of earth current telegraphy (T.P.S.) developed by the French Military Radiotelegraphic Service are detailed, together with a brief historical *resumé* of the method, concluding with a description of apparatus employed. Three-electrode valve amplifiers were used for reception.

1022. AIRCRAFT WIRELESS APPARATUS: CRYSTAL RECEIVERS. J. J. Honan. (*Wireless World*, 7, pp. 605—608, January, 1920; pp. 665—667, February, 1920; pp. 729—731, March, 1920.)

An illustrated description of Mark III. and Mark IV. short wave receiving tuners used by the R.A.F.

1023. THE IMPERIAL WIRELESS COMMITTEE (1919—1920). (*Wireless World*, 8, p. 306, July 10th, 1920—Abstract. *Nature*, 105, p. 594, July 8th, 1920—Abstract. *Electrical World*, 76, p. 124, July 17th, 1920—Abstract. *Electrical Review*, 87, p. 16, July 2nd, 1920, and pp. 42—43, July 9th, 1920—Abstract. *Telegraph and Telephone Age*, 38, p. 413, August 1st, 1920—Abstract. *Electrician*, 85, pp. 1 and 42, July 2nd, 1920—Abstract.)

Report of the Committee published July, 1920—see RADIO REVIEW, 1, pp. 543—544, August, 1920, for Abstract.

1024. THE FIRST ANNUAL CONFERENCE OF AMATEUR WIRELESS SOCIETIES. (*Wireless World*, 8, pp. 16—20, April 3rd, 1920.)

A verbatim report of the proceedings at the conference held on February 27th under the chairmanship of Sir Charles Bright.

1025. A SWEDISH RADIOTELEGRAPHIC INVENTION. (*Revue Générale de l'Électricité*, 7, p. 35B, January 31st, 1920.)

A brief note relative to a new method of secret transmission, but giving no details.

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1026. Wireless Telegraphy Laws (Japan). (*Journal Télégraphique*, 44, pp. 42—45, March 25th, 1920; pp. 57—59, April 25th, 1920.)

1027. Japanese Laws *re* Private Wireless Installations. (*Journal Télégraphique*, 44, pp. 91—96, June 25th, 1920.)

1028. The Use of Wireless for Commercial Traffic. H. Thurn. (*Elektrotechnische Zeitschrift*, 40, pp. 545—546, October 30th, 1919. *Revue Générale de l'Électricité*, 7, p. 85D, March 13th, 1920, Abstract.)
See also Radio Review Abstract No. 539, July, 1920.

1029. Telegraphy, Telephony and Wireless in the War: Report of the Chief Signal Officer for the Year ended June 30th, 1919. (*Science Abstracts*, 23B, pp. 214—215, Abstract No. 425, April, 1920—Abstract.)

1030. Wireless Wonders at Woolwich. (*English Mechanic*, 111, p. 256, June 25th, 1920.)
A brief *resumé* of some of the wartime work carried out at the Signals Experimental Establishment, Woolwich.

1031. Wireless Telegraphy on Railways. (*Telefunken Zeitung*, 3, No. 18, pp. 36—44, October, 1919.)
A popular description of the use of wireless telegraphy and telephony in railway work.

1032. Development of the Telefunken Company. (*Telefunken Zeitung*, 3, No. 18, pp. 29—35, October, 1919.)
Figures are given illustrating the growth of the company especially since 1914.

1033. Wireless Strays from the Unknown. G. Marconi. (*Electrician*, 84, p. 122, January 30th, 1919.)
A letter protesting against recent journalistic statements as to "mysterious messages from the unknown," and disclaiming assertions as to messages being received from Mars.

1034. The Discovery of Electromagnetic Waves. P. R. Coursey. (*Wireless World*, 8, pp. 73—75, May 1st, 1920. *Technical Review*, 6, p. 549, June 22nd, 1920—Abstract.)
This article briefly recapitulates Hertz's work leading up to the discovery of electromagnetic waves, and the arrangement used for setting up stationary waves on a long horizontal wire.

1035. French Radiotelegraphic System. (*Electrician*, 84, p. 678, June 18th, 1920.)
A few particulars are given of the French Government scheme for supplementing the existing telegraph and cable systems of communication. It is divided into four sections; the first to provide communication with ships at sea; the second to maintain regular communication with the mountainous regions of the country; the third to provide communication between France and other parts of Europe and the fourth for linking up the French colonies, including Saigon, Noumea and Tahiti. Stations capable of transmitting 7,500 miles are to be erected at Paris, Saigon and Tahiti and less powerful stations at a number of other colonial points.

1036. A Trip with a Radio Man across the Atlantic. J. Dunsheath. (*Telegraph and Telephone Age*, 38, pp. 334—335, June 16th, 1920.)
This article includes many references to wireless stations picked up at various distances across the Atlantic and concludes with a plea for the publication of more exact information as to the transmission times of meteorological messages, time signals, ice warnings, press, etc.

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1037. Regulations for Small Wireless Receiving Stations. (*L'Électricien*, 50, p. 115, March 15th, 1920.)
Gives particulars of the conditions under which the use of receiving stations is allowed in France for reception of time signals, etc.

1038. The Langmuir Condensation Pump. L. A. Hawkins. (*Everyday Engineering Magazine*, 9, p. 130, May, 1920.)
A brief illustrated description.

1039. The Times of Transmission of the Principal Wireless Stations. P. Corret. (*La T.S.F. Moderne*, 1, pp. 50—56, May, 1920.)
An extensive time table is given of transmissions from the most important European stations. The call letters, wavelength and type of wave are given, together with an indication of the nature of the messages sent (time signals, weather signals, press, etc.). The particulars given are corrected to the end of May, 1920.

1040. Direction Finding Stations. (*Admiralty Notice to Mariners*, Nos. 363 and 524, 1920. *Wireless World*, 8, p. 104, May 1st, 1920—Abstract.)
Information is furnished with regard to the working arrangements and regulations for Direction Finding Stations available for use by the Mercantile Marine in Great Britain, Canada, United States, France, Italy, and Germany.

1041. Report of the Activities of the "Telegraphen-Versuchsamt" in 1919. K. W. Wagner. (*Telegraphen- und Fernsprech-Technik*, pp. 1—7, April, 1920; and pp. 21—28, May, 1920.)
A brief review of the researches carried out by the telegraph administration, covering the whole field of telegraphy and telephony including wireless. Fourteen researches are reported dealing with wireless telegraphy and telephony, including—Installation of high-speed Wheatstone wireless system Berlin—Weimar; The freedom from disturbance of different receiving systems; Measurement of small coupling; High-voltage Wehnelt rectifiers; Effect of sending by altering the wavelength; The constancy of frequency in different sending systems; Wireless telephony; Reception on the telegraphone; Tests on the Eilvese receiving system.

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2. Books.

Grundriss der Funken-Telegraphie in Gemeinverständlicher Darstellung. By Dr. Franz Fuchs. (Munich: *R. Oldenbourg*. Eleventh Edition, 1920. Pp. 73. Price 2.75 M.)

This is the eleventh edition of this little book which was written during the war for the instruction of the great number of untrained men who were drafted into the wireless signalling section of the army. It assumes no previous electrical knowledge and seeks by means of simple explanations and numerous diagrams to give a knowledge of the principles involved. Although dealing principally with the systems employed by the German Army in the field, a section has been added describing the uses of three electrode valves. The last two diagrams in the book are somewhat misleading, but on the whole it is an admirable book for the purpose in view. The descriptions are clear and to the point and the diagrams are excellent.

G. W. O. H.

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DE INVLOED VAN EEN GEIONISEERD GAS OP HET VOORTSCHRIJDEN VAN ELECTROMAGNETISCHE GOLVEN EN TOEPASSINGEN DAARVAN OP HET GEBIED DER DRAADLOOZE TELEGRAPHIE EN BIJ METINGEN AAN GLIMLICHTONTLADINGEN. [THE EFFECT OF IONISED GAS ON THE TRANSMISSION OF ELECTROMAGNETIC WAVES AND ITS APPLICATION TO RADIOTELEGRAPHY.] By Balth. van der Pol. (Haarlem, 1920. Pp. 87.) [In Dutch.]

This reprint of a thesis presented by the author for the degree of Doctor of Science of the University of Utrecht, contains a description of a number of experiments made with the object of determining the effect of ionisation on the conductivity and apparent dielectric constant of a gas. An introduction is devoted to a review of the work of Macdonald, Poincaré, Nicholson and Watson on the mathematical side and of Austin on the experimental side of long distance transmission. The theory of Eccles and Salpeter that the velocity of the waves in the upper atmosphere is increased owing to the effect of free ions in reducing the apparent dielectric constant is then explained and a number of experiments with the object of confirming this theory are then described. The wavelengths employed were only between 1 and 2 metres, and the method consisted in setting up waves on a pair of Lecher wires by means of a Blondlot oscillator, except that in a few tests a three-electrode valve was employed. Attempts to transmit waves through a cylinder enclosing the Lecher wires failed owing to the absorption which occurred when the gas was ionised to any considerable extent. The method was therefore modified and the properties of the ionised gas determined by connecting the open ends of the Lecher wires through a vacuum condenser, the dielectric of which could be ionised by means of separate electrodes supplied at a high voltage. The Lecher wires were made telescopic and the P.D. was explored by means of a Duddell thermo-galvanometer connected to two exploring wires which were not brought into actual contact with the Lecher wires. A glow discharge was maintained within the vacuum condenser and the gas pressure varied between 0·345 and 2·19 mm.; this altered the reflecting properties of the condenser and changed both the distance to the first potential node, and the amplitude of the oscillation set up. From the results obtained the author considers that under some conditions there is a reduction of the apparent dielectric constant of the ionised vacuous space.

The author investigates the transverse conductivity of a vacuum tube along which a glow discharge takes place. The tube is placed between two electrodes which partially embrace it; these two electrodes constitute a condenser, and by sliding the tube along between the electrodes the conductivity can be determined at any point without the use of exploring wires.

G. W. O. H.

ERRATA.

Page 593, *Fig.* 6, *the equation of the dotted curve should read:*
$\tan \delta = -7{\cdot}5^\circ \sin 2\phi$.

Page 625, *footnote, for* Abstract No. 8 *read* Abstract No. 830.

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THE RADIO REVIEW

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THE
RADIO REVIEW

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Recent Commercial Developments in Wireless.

By Major H. MACCALLUM.

The remarkable technical progress which has taken place during the last few years has resulted in the development of a number of new commercial types of apparatus, some representative examples of which it is the purpose of the present article to describe.

The three-electrode valve of the "hard" or high vacuum type, perfected during the war, has formed the basis of a number of new patterns of transmitter. Standard continuous wave telegraph sets of from 100 watts up to 25 kW, in which the three-electrode valve is the source of high frequency energy, are commercially available at the present time, and installations of higher powers are in course of erection at commercial wireless stations. Standard wireless telephone sets up to 6 kW are also obtainable, and installations rated at from 15 to 25 kW have passed through prolonged tests under actual working conditions, with entirely satisfactory results.

In the smaller sets it is usual to combine the telephone and telegraph equipment, the source of high frequency energy being common to both, and the whole apparatus with the exception of the motor generator and main switches is conveniently mounted in a wooden cabinet, together with the receiving gear. An example of this type of construction will be found in the 1½ kW cabinet set described later. Smaller sets are arranged for mounting in vehicles or for transport by pack animals, and the special conditions on aircraft are met by the provision of extremely light and compact apparatus obtaining its energy from a wind driven generator and operated by a remote control unit, which allows the transmitting and receiving gear to be housed in a convenient and suitable position, while the key, microphone, telephones, switches, etc., are easily accessible to the operator. Larger installations are usually built up on the panel or switchboard principle, and arranged in such a manner that the continuous wave transmitter is a complete unit, which can be adapted to telephony by the addition of an extra control panel carrying the modulating and control valves, together with certain refinements unnecessary in the case of telegraphy. The 6 kW installation described later is an example of the type referred to.

In the Mercantile Marine the necessity for an installation which is primarily suitable for use in connection with safety of life at sea, has resulted in the production of a combined "spark" and C.W. transmitter, by means of

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which S.O.S. calls can be sent out on "spark" while long distance communication is handled on continuous waves.

Early this year the ex-German liner *Imperator* was fitted with C.W. and "spark" by way of experiment, the apparatus being of a pattern not specially designed for installation on board ship. The results obtained were of such an encouraging and satisfactory nature that a number of other liners were fitted and a new set was specially designed to meet the demand. Simplified diagrams of connections of this set are shown in Figs. 1 and 2, and its general appearance is indicated in the photographs, Figs. 3 and 4.

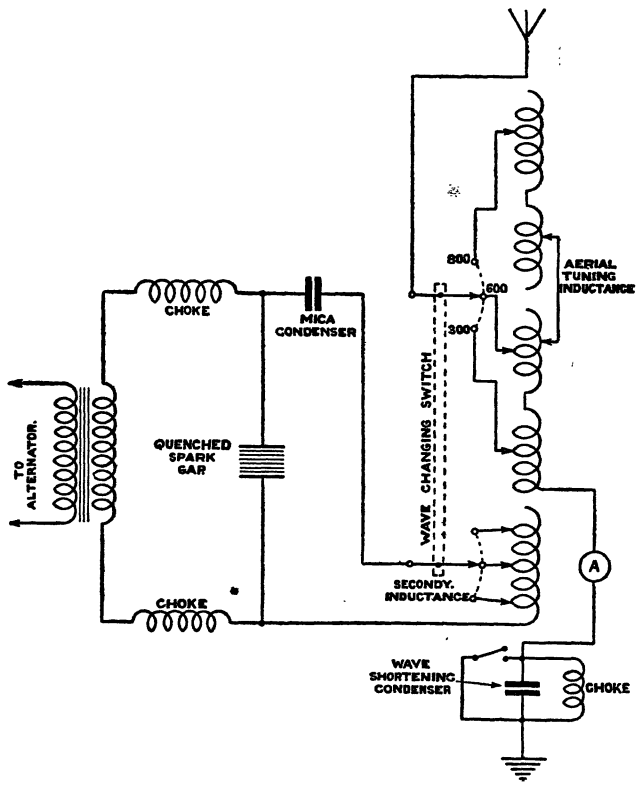

FIG. 1.—CONNECTIONS OF 1½ kW SHIP SET (SPARK CIRCUITS).

The aerial, earth connections and manipulating key are common to the two transmitters both of which derive their power from the same 500 cycle motor alternator with step-up transformer.

Arrangements are provided for working the set at reduced power in order to minimise interference when communicating short distances. This is effected on the C.W. transmitter by means of a power regulating choke with a sliding core which is connected in series with the primary of the power

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transformer. When the "spark" transmitter is in use, this choke is short circuited and reduction of power if required is obtained by cutting out one or more of the spark gaps.

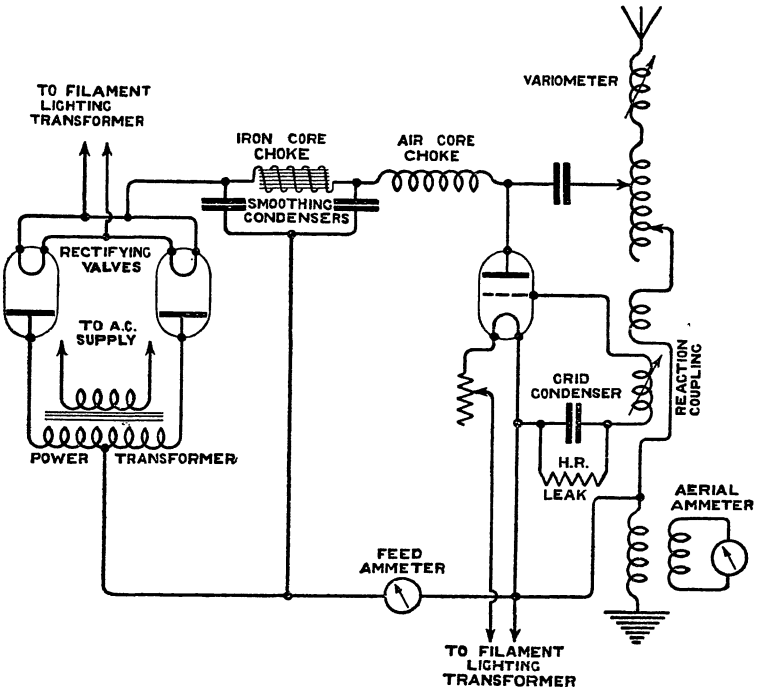

Fig. 2.—Connections of 1½ kW Ship Set (C.W. Circuits).

The change-over from one system to the other is effected by means of two switches. The first connects the power transformer secondary to the "spark" or C.W. transmitter, as desired, making the necessary connection to the middle point of the secondary winding in the latter case, and also connects the two primary windings of the transformer in parallel for C.W. working or in series for "spark" working.

The spark transmitter is designed to transmit on all wavelengths between 220 and 800 metres, the normal adjustments being for 450, 600 and 800 metres.

The three-way wave-changing switch which can be clearly seen in Fig. 3 controls both the primary and secondary circuits and enables a quick change to be made from any one of the three selected wavelengths to any other.

The inductance windings are of a patented flat spiral type, consisting of a double strip of copper bedded into the surface of an ebonite panel. Tappings can be made to any point of the spiral by means of special plugs which fit into the space between the two strips.

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The quenched gap is of the standard Marconi pattern illustrated in Fig. 5.

In this set space is saved by the employment of mica condensers in place of the more bulky glass and oil insulated pattern. These are contained in cast metal containers fitted with terminal covers of insulating material. The wave-shortening condenser, in the aerial circuit Fig. 1, is of the same type as that of the primary unit, differing only in capacity. When not required this condenser can be short circuited by means of a switch provided for the purpose.

The correct syntonisation of the primary and secondary circuits is indicated by means of an aerial ammeter of the transformer type.

The continuous wave transmitter is of the auto-coupled type. The circuits and valves are mounted on a panel (Fig. 4) approximating in size to that of the spark set.

The 500 cycle high tension alternating current supplied by the secondary winding of the transformer (Fig. 2) is rectified to a unidirectional pulsating current by means of rectifying valves of the M.R. 1 pattern (Fig. 6) operating on the familiar principle of the Fleming valve. By the use of two such rectifying valves and a centre connection from the transformer secondary winding a pulsating current of frequency equal to double the initial frequency is produced. Pulsations or ripples are smoothed out by a condenser of 0·25 μF capacity which is shunted with a large iron cored choking coil.

The oscillator (Fig. 7) is a single three-electrode valve of the M.T. 4 pattern, the anode of which is fed by the smoothed-out, rectified, alternating current, through an air cored choking coil the function of which is to obstruct the return of high frequency currents to the supply circuit. The negative connection to the filament is through a milliammeter which indicates the H.T. feed current to the valve.

The grid of the power valve is connected through a reaction coil and condenser, shunted by a high resistance leak, to the secondary of the power valve filament lighting transformer and to earth. The reaction coil is electromagnetically coupled to the aerial tuning inductance.

The filaments of the two rectifying valves and the power valve are lighted from a small step-down transformer, the primary winding of which is connected to the slip rings of the rotary converter through two choke coils provided with adjustable iron cores. One of the chokes is used for adjusting the brilliancy of all three valve filaments by alteration to the primary voltage of the transformer. The power valve filament current is also adjustable independently of the rectifiers by means of a sliding resistance.

The function of the other choke, termed the compensating choke, is to prevent fluctuation in the brilliancy of the valves due to the drop in voltage which occurs when current is taken from the power transformer in the act of sending Morse signals. This choke is in series with the lighting transformer primary winding so long as the sending key is up, but is short circuited through a pair of subsidiary contacts when it is depressed. A second pair of contacts disconnects the grid condenser leak when the key is up and the main contacts make and break the primary of the power transformer thus controlling the high tension feed to the anode of the power valve.

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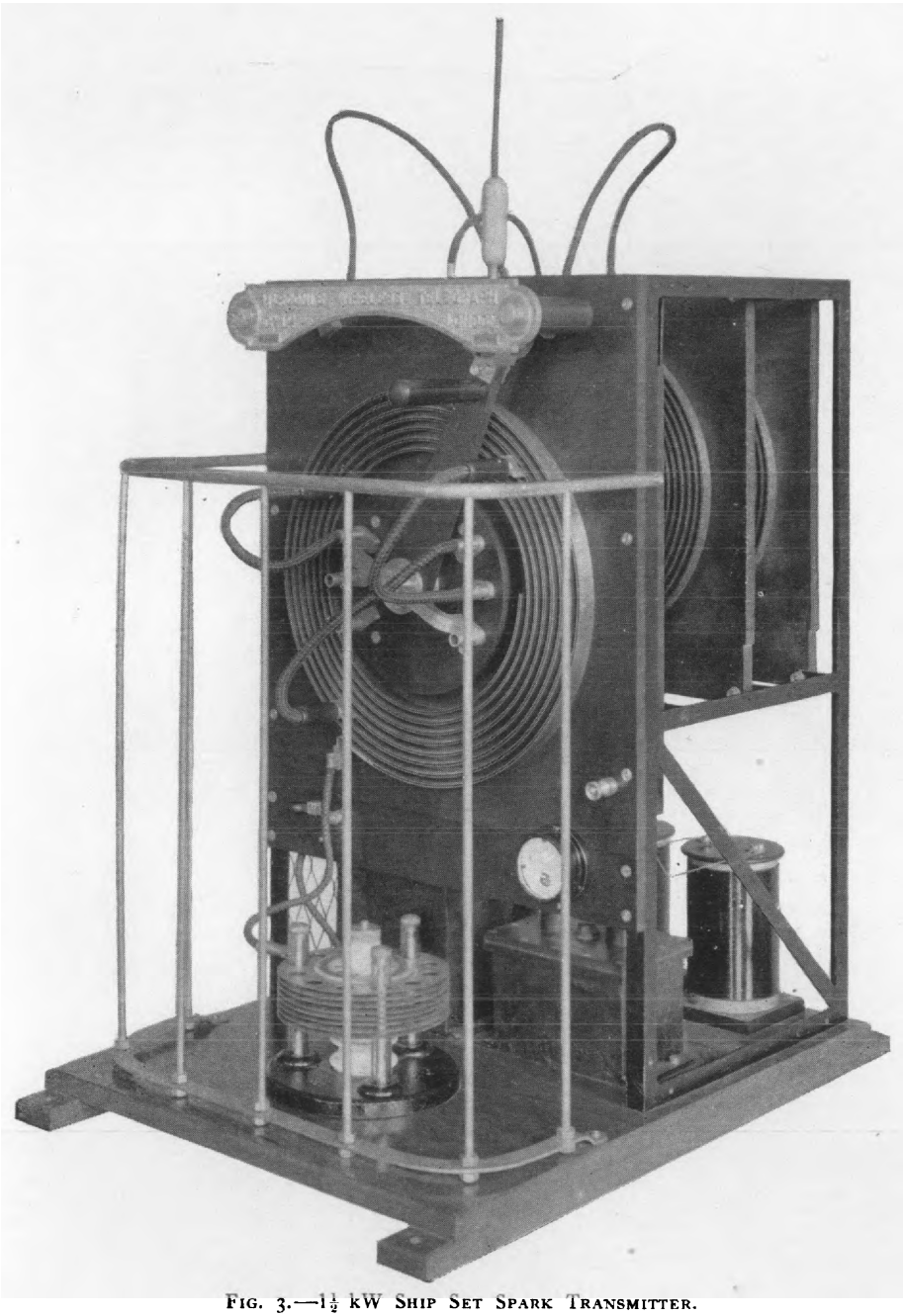

FIG. 3.—1½ kW SHIP SET SPARK TRANSMITTER.

(*To face p.* 688.)

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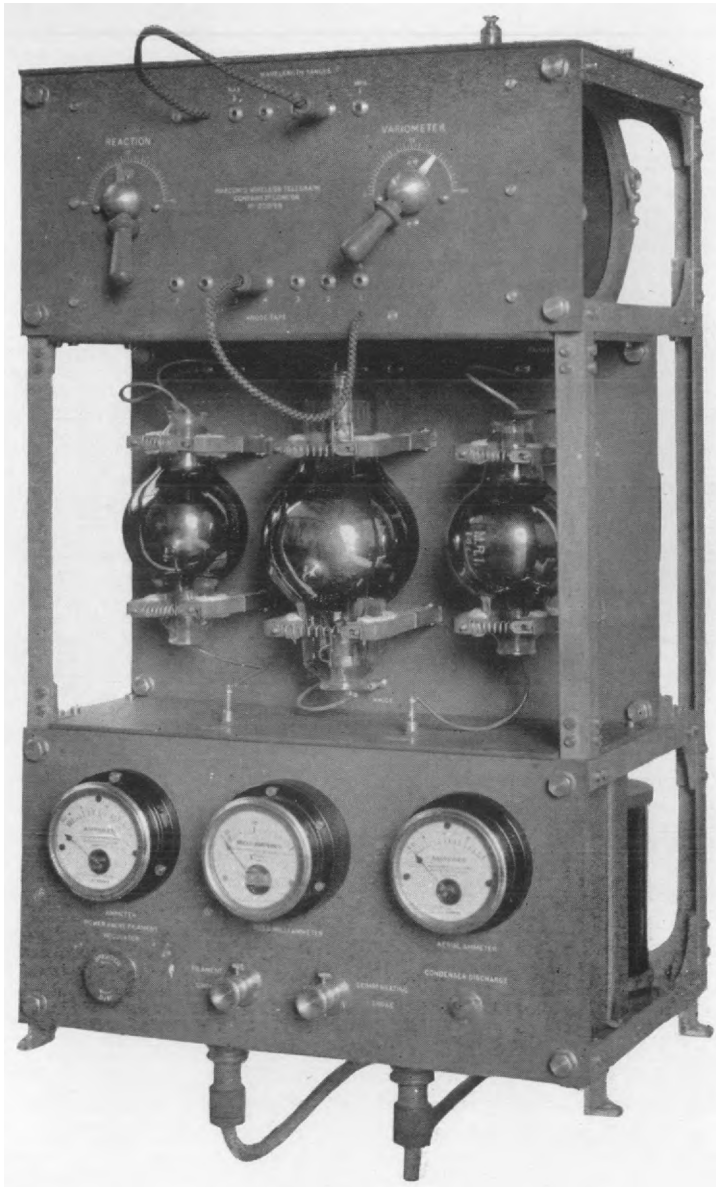

FIG. 4.—1½ kW SHIP SET C.W. TRANSMITTER.

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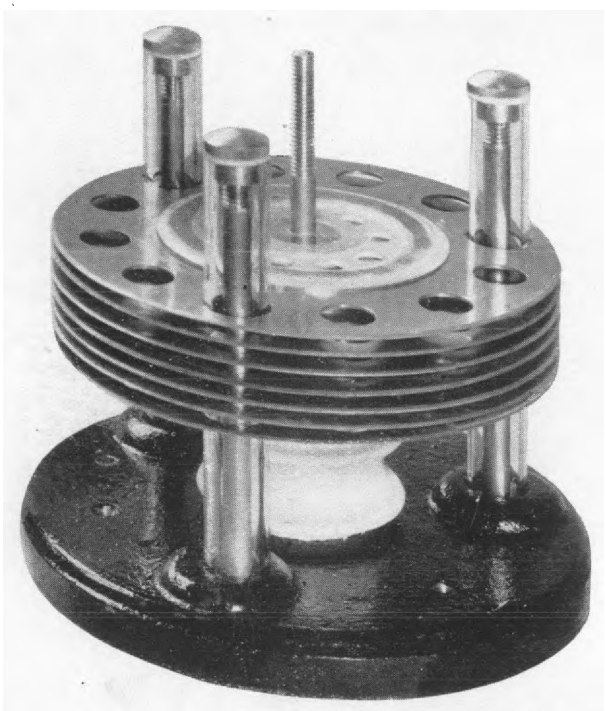

FIG. 5.—STANDARD MARCONI QUENCHED GAP (PARTLY ASSEMBLED).

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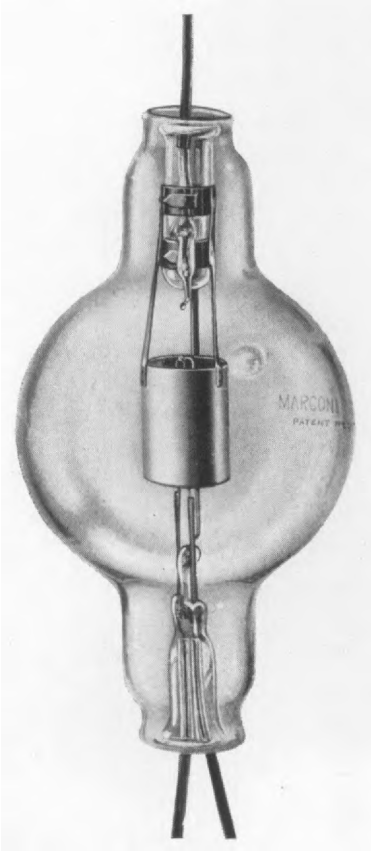

FIG. 6.—M.R. 1 RECTIFYING VALVE.

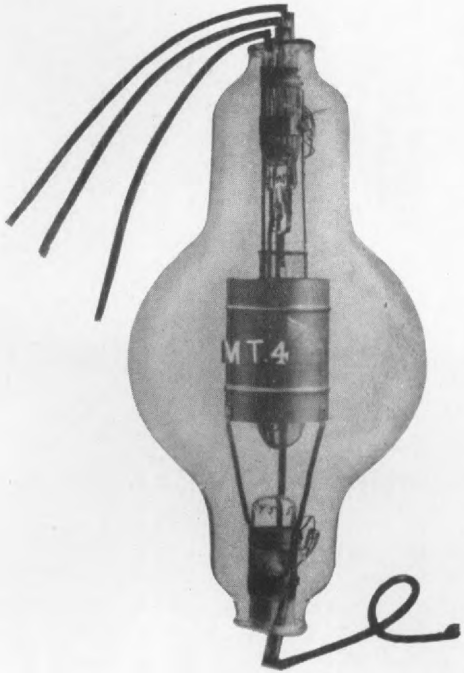

FIG. 7.—M.T. 4 TRANSMITTING VALVE.

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FIG. 8.—1½ kW CABINET SET FOR TELEGRAPHY AND TELEPHONY.

(*To face p.* 689.)

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A 1½ kW combined telegraph and telephone set of the cabinet type is illustrated in Fig. 8, and Fig. 9 is a simplified diagram of the transmitting circuits.

Referring to Fig. 8, the rectifying, control and power valves are mounted on a recessed panel of insulating material at the left of the cabinet. The receiving apparatus is on the right, and the transmitting aerial tuning inductance and reaction coil are supported on insulators at the top of the cabinet. The aerial and feed ammeters are seen on the left hand and centre respectively, the "send-receive" change-over switch at the centre, and in front of this the two transmitting keys. The speaking microphone hangs inside the cabinet on the extreme right.

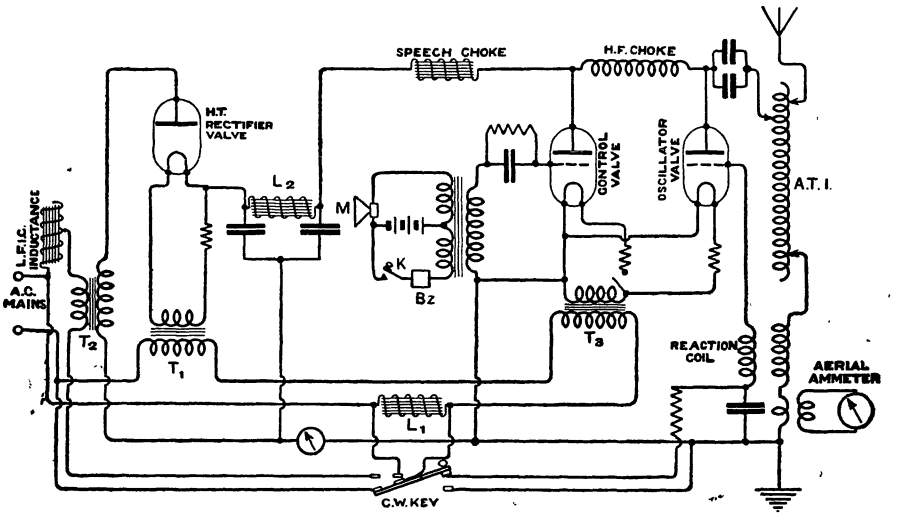

FIG. 9.—1½ kW CABINET SET, SIMPLIFIED DIAGRAM OF CONNECTIONS.

Bz = Buzzer; L_1 = Compensating Choke; T_1 and T_3 = Filament Transformers; M = Microphone; T_2 = Power Transformer; L_2 = Smoothing Choke; K = Tonic Train Key: ATI = Aerial Tuning Inductance.

For continuous wave telegraphy a Morse key interrupts, at one and the same time, the reaction circuit and the "anode" supply circuit, thus throwing the valve in and out of action without change of wavelength. The Morse key is also fitted with contacts which are connected across a choke coil in the primary circuit of the filament lighting transformer, so that the filament current remains constant during transmission. The key carries a switch at one side; for continuous wave transmission the switch is thrown over to the left, for telephony and "tonic train" it is moved to the right.

For telephony the amplitude of the oscillations due to the first valve is controlled by a second valve of the same size and pattern, fitted on the left hand side of the large valve panel. This valve has in its "grid" circuit the secondary of an audio-frequency transformer, the primary of which is wound in two halves, one half being connected to a microphone, the other to a high note buzzer and a Morse key. A six volt accumulator battery

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is common to both circuits. The high note buzzer and key are provided for use when it is desired to communicate by the "tonic train" method with stations which are not equipped for the reception of C.W. signals.

The anodes of the oscillator and control valves are fed with high tension direct current, which is obtained from the secondary winding of a step-up transformer by means of an M.R. 1 rectifying valve in circuit with a suitable smoothing-out choke. Referring to Fig. 9 it will be seen that the feed current passes through an iron cored "speech choke," which, on account of its high inductance, allows of speech frequency potential variations at the valve anodes while the high tension supply potential remains practically constant. A step-down transformer supplies current to the filaments of the three valves. This transformer has two independent secondaries, one of which feeds the oscillator and control valves, and the other, which is specially insulated, supplies the rectifier.

The receiving circuits are arranged for the reception of continuous wave, phone, tonic train, or spark signals, over a wavelength range from approximately 300 to 3,000 metres. When sharp tuning is not required the receiver is connected as in Fig. 10, which represents the normal watching or "stand-by" circuit. A multiple contact switch is provided, by operating which a secondary circuit may be introduced, and the connections rearranged as in Fig. 11. Under these conditions the tuning is very much sharper and the liability to interference is correspondingly reduced.

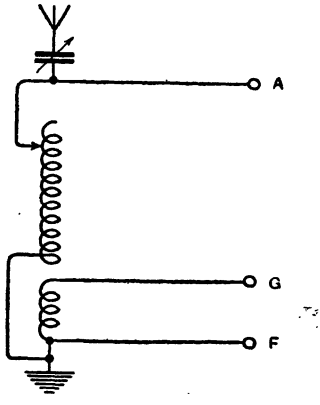

FIG. 10.—STAND-BY RECEPTION.

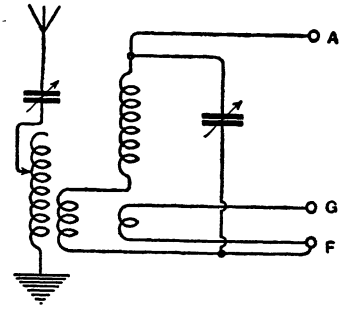

FIG. 11.—TUNED RECEPTION.

1½ kW CABINET SET, DIAGRAM OF TUNING CIRCUITS.

The terminals A G and F (Figs. 10 and 11) are connected to the corresponding terminals of a standard seven valve amplifying detector, which is incorporated in the receiving panel of the right hand side of the cabinet.

The change from transmission to reception or *vice versa* is effected instantaneously by a single movement of a multiple-contact change-over switch. The normal position of the switch handle is to the left, in which position the aerial is connected to the receiving tuner and the battery circuit

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through the microphone broken, the set being in a condition for reception. On throwing the switch to the right, the aerial is put to earth through the aerial ammeter, the battery is connected to the microphone or buzzer, and the alternating current circuit is closed first through the lighting transformer, and then through the power transformer, thus placing the set in condition for transmission. When the switch is in the "receive" position, it will be noted that the transmitting gear is isolated from the supply, but it remains alive owing to the charge held by the smoothing-out condensers in the rectifier circuit. Provision is made for discharging these condensers by means of an ebonite press button, which is operated before live parts of the gear are handled.

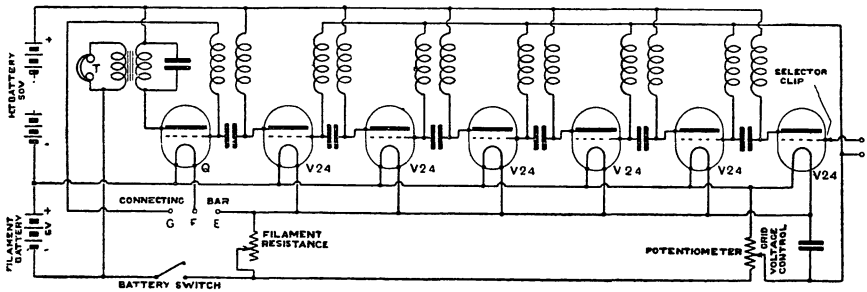

FIG. 12.—SIMPLIFIED DIAGRAM OF CONNECTIONS OF SEVEN VALVE AMPLIFYING DETECTOR.

The amplifying detector is of the aperiodic pattern, that is to say its resonance curve has no definite peak though the amplification value is not uniform over the whole range of wavelengths. Fig. 12 is a simplified diagram of connections, on referring to which it will be seen that there are six valves of the "V. 24" pattern and one "Q" valve connected in cascade. The grids of the first six valves, which are for high frequency amplification, are connected to the slider of the potentiometer across the filament lighting battery. The "Q" valve, which is for rectification, is designed to work at a definite potential and is connected, through its transformer, to the negative side of the filament.

The cascade connection referred to above is an arrangement whereby each successive valve increases the amplitude of the oscillation applied to it by a constant ratio, the resulting amplification following a geometrical progression. The incoming oscillations are led to the grid of the first valve, the plate circuit of which is connected *via* the primary of a specially designed transformer to the positive pole of the H.T. battery, and thence to the filament. The amplified oscillation from the plate circuit of one valve is transferred to the grid of the next by the use of two distinct principles, the combination of which increases the efficiency of the amplification. Firstly, there is the inductive coupling of the two windings of the transformer; secondly, owing to the high resistance of the coils, there is an appreciable voltage drop in the plate circuit when current is flowing, and by means of small condensers and also of the capacity between the windings themselves, variations of this

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voltage drop, caused by incoming signals, are communicated to the grid of the next valve.

With most cascade arrangements there is a tendency for the valves to generate persistent oscillations, and if this occurs the amplification is greatly reduced. In the pattern here described, such a tendency can be checked by suitably adjusting the potentiometer.

The reaction coil in the tuner, Figs. 10 and 11, is connected to the terminals G and F of the amplifier from which the connecting bar is removed. If the reaction coupling is made sufficiently tight, the valves will be caused to generate high-frequency persistent oscillations, thereby rendering possible the "auto-beat" method of continuous wave reception. Also by carefully adjusting the reaction so that the valves are on the point of oscillation, the amplification of spark signals may be increased.

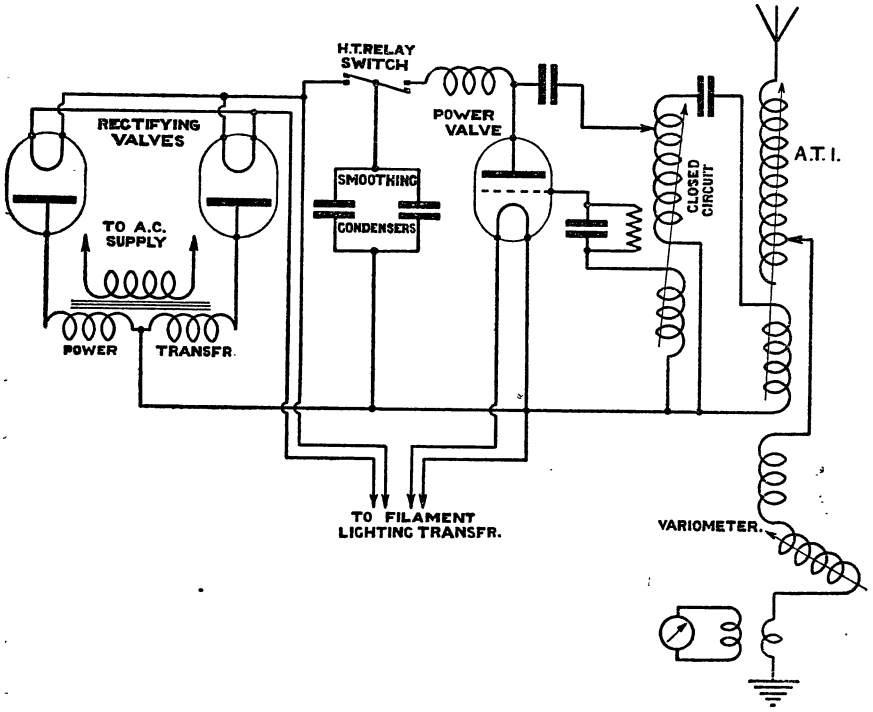

FIG. 14.—6 kW VALVE SET, SIMPLIFIED DIAGRAM OF CONNECTIONS FOR TELEGRAPHY.

As previously indicated valve transmitters of larger output are designed on the lines of a power switchboard, and in the case of the 6 kW set, with a description of which it is proposed to complete this brief survey of modern commercial developments, all the switches necessary for the operation of the set are controlled by electrically operated relays.

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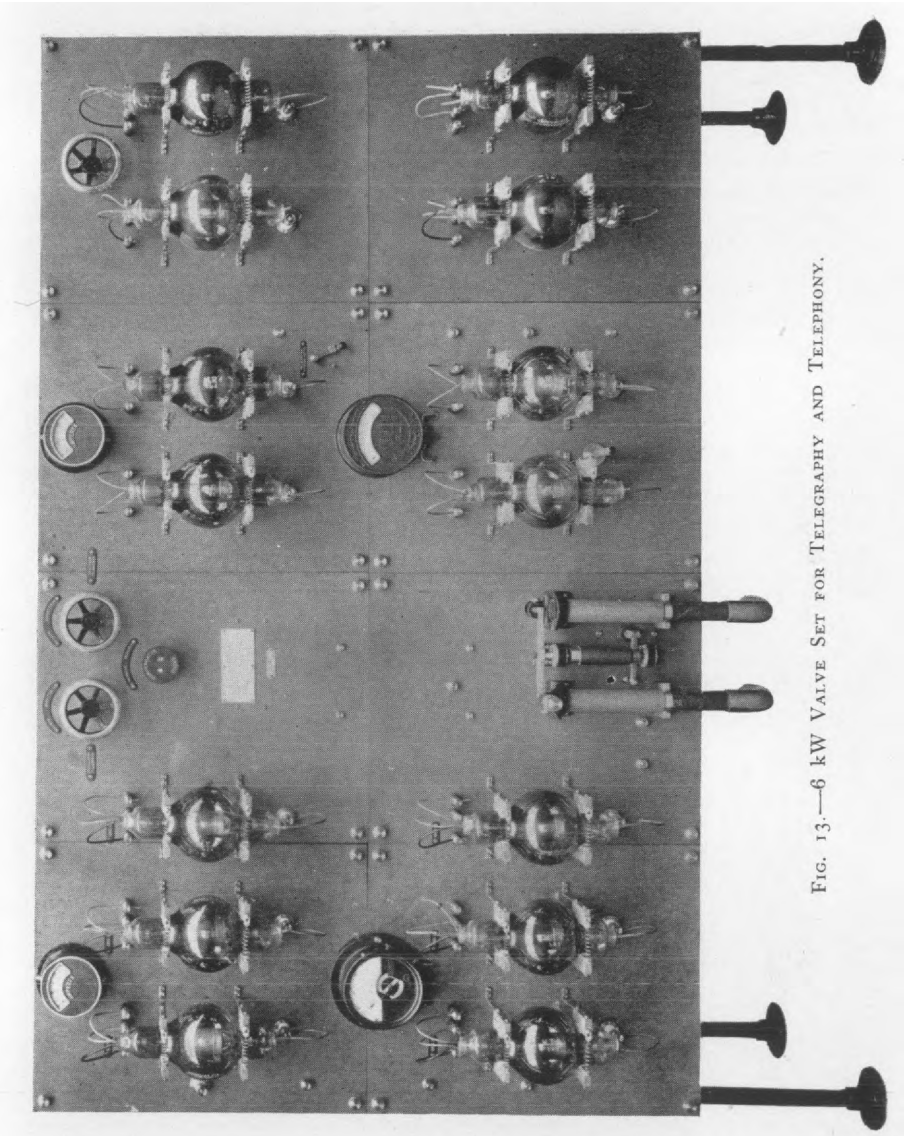

FIG. 13.—6 kW VALVE SET FOR TELEGRAPHY AND TELEPHONY.

(*To face p.* 692.)

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The complete installation consists of the following :—

(*a*) The panel on which are mounted the valves and relays with their circuits and accessories (see Fig. 13).

(*b*) The aerial and closed circuit inductances with coupling and reaction coils, variometer and closed circuit condenser.

(*c*) The power unit, consisting of a motor generator, wound to suit the available direct current voltage and generating alternating current at 500 volts 300 cycles.

(*d*) The remote control unit, consisting of the manipulating key, the microphone and three switches.

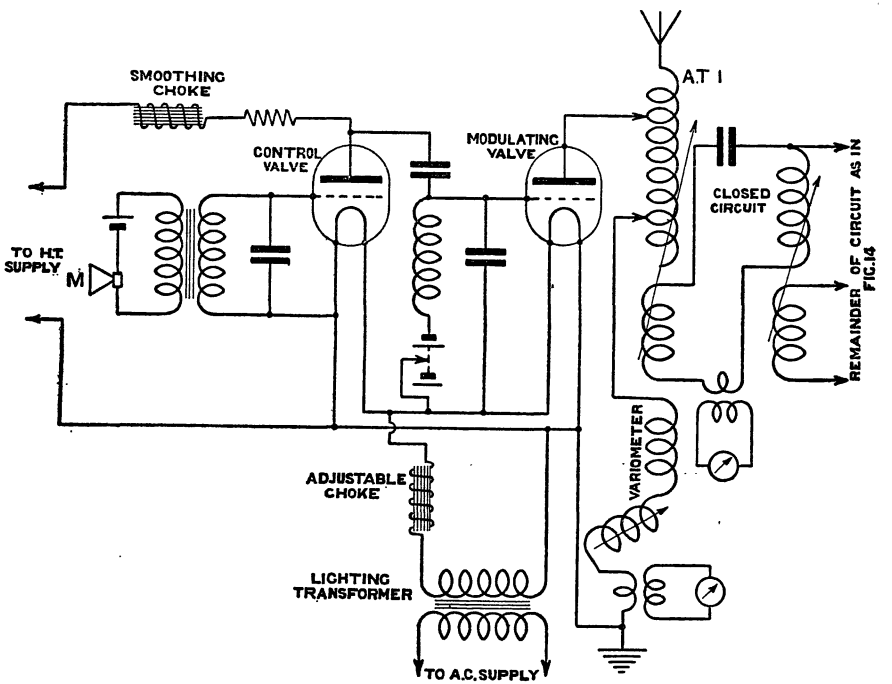

Fig. 15.—6 kW Valve Set, Simplified Diagram of Connections for Telephony.

Four rectifying valves of the type illustrated in Fig. 17 are used in providing the high tension supply for the valve anodes by the method previously described.

The standard equipment is designed for transmission on wavelengths from 2,000 to 4,000 metres, with an aerial of 0·003μF capacity, having a natural wavelength of 1,000 metres. With larger aerials correspondingly greater wavelengths are obtainable without loss of efficiency.

The essential features of the circuits are shown in the simplified diagrams in Figs. 14 and 15. The first illustrates the working of the set when used for telegraphy, while the second shows the circuit for telephony.

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The switching arrangements and relays by which the change over from telegraphy to telephony is effected, are shown in a more detailed diagram (Fig. 16).

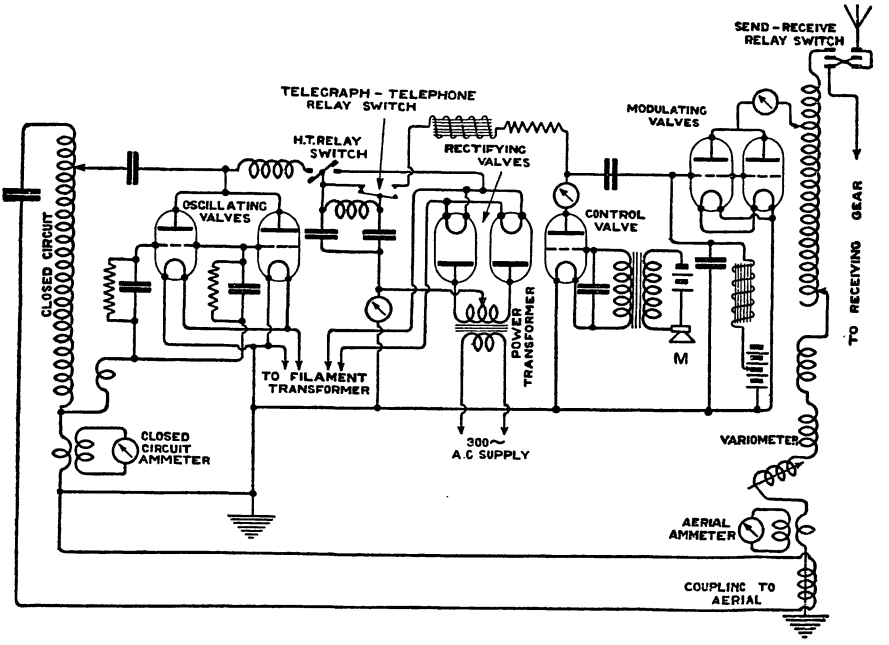

FIG. 16.—6 kW VALVE SET, DETAILED DIAGRAM OF CONNECTIONS.

The aerial circuit is loosely coupled to a closed oscillation circuit, consisting of an inductance and a condenser, which derives energy from a bank of 6 three-electrode valves of the type illustrated in Fig. 7. For the sake of simplicity only one valve is shown in Fig. 14. The common grid circuits of these valves are coupled back to the main circuit, so that continuous oscillations are produced when the power is applied.

Transmission of telegraphic signals is effected by means of a Morse key controlling a relay switch in the high-tension supply circuit, the spark at the contacts being quenched by an air blast from a motor-driven blower. A second relay, also operated by the key, short circuits an adjustable choke in series with the primary of the filament transformer in order to maintain the filament current constant while transmission is taking place.

The diagram in Fig. 15 illustrates the principle of working of the telephonic control circuit. Unnecessary complication has been avoided in this diagram by omitting most of those parts of the circuit which remain the same for telegraphy and telephony, and showing only one modulator valve instead of three in parallel.

The three modulating valves and single control valve can be seen in

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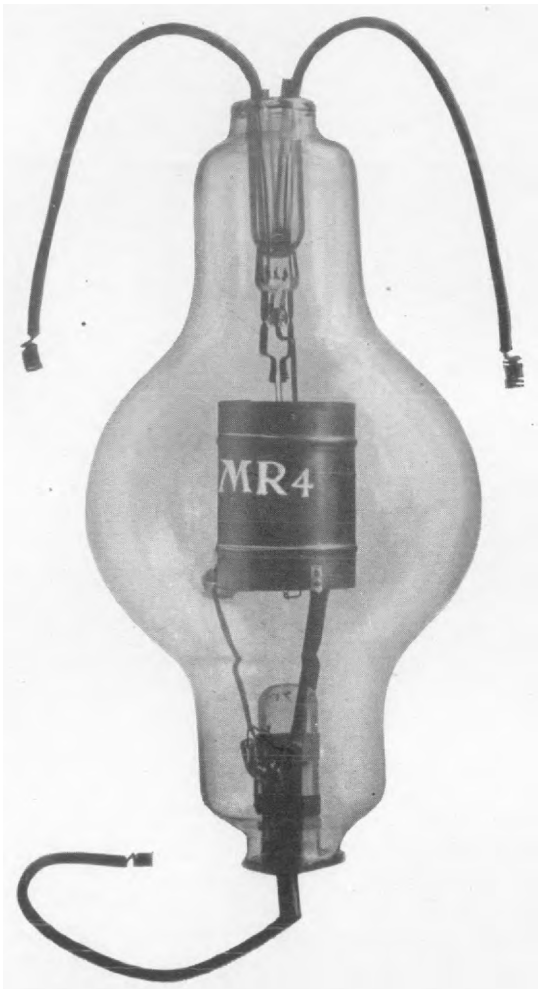

FIG. 17.—M.R. 4 RECTIFYING VALVE.

(*To face p. 694*)

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Fig. 13 mounted on the extreme right hand section of the panel. It will be seen from Fig. 15 that the modulating valves form a resistance in parallel with the aerial, thus absorbing a portion of the energy which would otherwise be radiated. The voice, actuating the microphone, indirectly causes this resistance to vary through the medium of the control valve, which amplifies the variations caused by the microphone. The anode current in this valve is obtained from the same source and rectified by the same valves as the anode current in the power valves. The microphone is incorporated in the remote control unit.

In addition to keying for telegraphy and speaking for telephony, the following operations are also performed by means of the remote control :—

(*a*) *Telegraphy-Telephony Change Over.*—When the switch provided for this purpose is put over from telegraphy to telephony, relays are actuated which close the filament lighting circuit of the four speech valves, switch on the high tension supply to the control valve, and short circuit the transmitting key. At the same time an extra choke is inserted, in the smoothing condenser circuits, in order to produce a greater steadying effect on the rectified alternating current. These operations are reversed when the switch is changed back to telegraphy.

(*b*) *Send-Receive Change Over.*—The " send-receive " switch actuates relay controlling switches which, at " receive " cut off the power from the key and connect the aerial to the receiver, at the same time disconnecting it from the transmitting circuit.

(*c*) *Starting and Stopping Motor.*—This is effected by a third switch, which controls a relay actuating the starting handle of the motor, thus enabling the starting up and shutting down of the set to be effected by the operator.

Critique of Capt. Robinson's Article " A Method of Direction Finding." *

By Major C. E. PRINCE, O.B.E.

The system of Direction Finding set forth in Captain Robinson's articles in Nos. 5 and 6 of the Radio Review† opens up some interesting points as to its relationship with other and earlier methods, and in many ways invites comments.

Modern direction finding methods are the ultimate outcome of many years of work and progress of many minds, during which time most of the possibilities inherent in present knowledge have been passed under review ; so

* Received September 3rd, 1920.

† Radio Review, 1, pp. 213—219, February, 1920, and pp. 265—275, March, 1920.

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that many a so-called novelty is little else than some particular recombination of the well-known elements, or differs only verbally from older practice. The present article is an attempt to analyse the claims made for Captain Robinson's system.

It was in 1905 that Marconi discovered the unsymmetrical radiation of a horizontally bent aerial, but although several ingenious methods (such as that of the 1909 patent of Captain H. J. Round) were devised for direction finding by means of such *directional* aerials, which have no absolute zero direction, these methods were but a stage on the road of progress, and need not detain us here. Nearly all modern work makes use (to keep to the nomenclature which the present writer has sought to standardise)* only of *directive* aerial systems; that is those which give a figure-of-eight polar curve having a complete zero in one plane.

The genesis of the *directive* aerial was contained in a suggestive patent of Mr. S. G. Brown in 1899, the fundamental idea of which is that of using two open vertical aerials half a wavelength apart; but the closed circuit loop or frame aerial is now the sole surviving directive arrangement.

This was introduced into the Bellini-Tosi system by the present writer in 1912, but, apart from its use in such combination, the rotating single frame aerial is now a common device.

Now there are two basic methods of employing a loop or *directive* aerial to determine the direction of an arriving wave which is sweeping over the region occupied by the observer.

The first and most primitive is to rotate the loop in space, and from the observed intensities in varying planes, to find the required direction. Except for secondary considerations (such as convenience, or accuracy), it is immaterial whether observations are made to the maximum or minimum.

This method however, is cumbrous, and an improved method—which is the essence of the Bellini-Tosi system—is to employ two directive aerials fixed in space at right angles, and to connect these each to a small reproduction of itself inside a "radiogoniometer." The latter will then form a little artificial world, as it were, in which the plane of the field produced by the signal will rotate in sympathy with the field of the larger real world.

The original single plane loop of the primitive system can now be reduced to a small "exploring coil" or loop, rotating in the artificial world.

It is plain that whether the final exploring loop rotates in the real or artificial world is a matter which does not affect its essential *modus operandi*. One cannot therefore, class or criticise either the primitive or the Bellini system by any actions depending upon the polar curve of the exploring loop itself; and it is solely the mathematical nature of the curve that decrees that observations on the maximum are flat and indeterminate, but those on the minimum, where the rate of change is greatest, are sharp and decisive.

The implication then, contained in (a) and (b) on page 214 of Captain Robinson's article is somewhat unjust. Observation about the minimum is not an essential of these two methods, but is indeed employed, on account

* See "The Wireless Direction Finder," C. E. Prince (*Year Book of Wireless Telegraphy and Telephony*, 1913, pp. 306—317).

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of its superior accuracy: and I propose to show that Captain Robinson's system does the like.

Let us now analyse the latter.

His apparatus consists of an aerial system, rotating, as in the primitive method, in the world-field; but composed of two loops rigidly fixed at right angles one with another. Suppose a direction is just being determined by it, and we consider the position of the coils. One of these, the "main" coil, is in the plane of the arriving signal, and consequently the variation of signal strength by a small movement of a few degrees is negligible.* This may therefore be considered a signal of constant strength, within the limits of searching, and hence this coil takes no part in the determination of direction.

But at right angles to this lies the other rather unhappily named "auxiliary" coil, which really does all the work! This coil is at right angles to the arriving wave, and is therefore working about its minimum position, where the rate of change is greatest. Any variation of signal strength due to rotation of the system will then be due to the action of this coil alone, which is in fact taking observations on the minimum; and the whole thing resolves itself into our original primitive loop, but with the addition of a constant signal.

This constant signal may have advantages or conveniences from the operator's point of view, but takes no part, as we have shown, in helping to determine direction.

We see therefore, that this system is in no way free from the disabilities of minimum observations described on page 214. Its accuracy also depends on strength of signal in exactly the same way. If in a plain primitive loop system the loop has to be moved $x°$ from zero in the world-field before a signal becomes audible, so a similar change of angle will be necessary in the Robinson system before any *variation* of signal strength becomes audible.

The only real advantages of the method then, are the secondary and practical ones mentioned in the last paragraph of the introduction. It also carries the disadvantage of ambiguity of two planes touched on by the author on page 265. Though dismissed somewhat lightly, any system suffering from such ambiguity has always been classed (in directional work) as essentially inferior to one not having it. The author seems to imply that there is some real difference between the so-called "main" and "auxiliary" coils; but assuming for the moment that the two coils are equal, we see that there is no means of deciding which of two planes—that is four directions—the signal is coming from, since either of the coils may act as "main" or "auxiliary" indifferently. A preliminary reading with one of the coils cut out of action is needful to eliminate one of these planes, before the reading proper is taken. This is necessary as long as one of the coils is not sensibly negligible in comparison with the other.

It will be observed though, that Captain Robinson does not make the two loops equal in area-turns, that is, receiving power, and on page 219 an apparently elaborate table is given of sensitiveness for various ratios of

* See curve aa, Fig. 3, of Captain Robinson's article (Radio Review, p. 217, February, 1920).

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"auxiliary" to "main" coil. This table, however, when plotted out, is simply a straight line; and merely amounts to the statement—the larger the auxiliary coil (relative to the other), the better—which is hardly surprising since it is that coil alone which, as we have seen, is actually concerned in the determination; and any effect of the constant-signal or main coil is detrimental to direction-sensitiveness. This can be seen even by inspection of his diagram (Fig. 3), where the slope of the combined curve cc, is somewhat less advantageously steep than that of the original "auxiliary" coil curve bb.

In spite therefore, of the imposing effect of mathematical and tabular expressions, we come back to the conclusion that this system is nothing more than our old friend the single loop rotated in the world-field, reading about the minimum (with a constant signal added for the convenience of the operator) while the switching over or reversal is equivalent to the mechanical rotation of the loop. This latter point, which is not mentioned by the inventor, seems really the basic point of the system.

Let us now approach the subject from another point of view. If we go back for convenience of thinking to the case in which the auxiliary and main coils are equal, we see at once that the aerial system may be considered as two exploring coils rigidly connected together, so that electrical switching can replace mechanical rotation.

A scheme embodying this idea was devised by Captain H. J. Round about 1913 as a corollary of his patent of 1909. In this a double exploring coil made up of two equal rigidly connected coils, was used, and the receiver was switched rapidly from one to the other. When there was no change of signal strength, the two coils were known to lie symmetrically about the plane of the required direction. Thus both coils were active, and working on a part of the curve where the rate of change is large: it is essentially immaterial whether they are made to work about the minimum or maximum axis, or whether they are set at right angles, or another angle.

The fact that the double exploring coil worked in the radiogoniometer rather than the world-field, was also, by what has been said already, a mere matter of choice; and it is difficult to see in what respect Captain Robinson's system differs essentially from the earlier one, or is any improvement on it.

The setting of one of these coils in the maximum and the other in the minimum position of the field, is merely an extreme case in the adjustment or employment of it, which seems to forfeit one of the best features of Captain Round's scheme of working both coils on a rapidly-changing portion of the curve; and which tends, as we have shown, to revert to the primitive loop. In both methods the exploring system was, after a reading, left at rest, indicating the required direction.

Again if we do allow some credit or essential difference to lie in the disparity of the loops and their particular method of employment, it then verges on a method suggested by the present writer* in which one *directive* and one non-directional aerial are employed, except that in this patent the loop or directive aerial being very large, and principally intended for ship installations, was not rotatable. Consequently the direction had to be determined

* *British Patent* 2457/1912.

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by the strength of signal on the loop relative to what it would have been if in the plane of the loop. For this comparison the circular polar curve of the non-directional aerial served as a standard, and it is fair to say that Captain Robinson's particular use of two such aerials was not claimed.

So, we see that, in general, as respects the direction determination only, the real essence of his method is the substitution of switching for rotation, and that by the ingenious method of connection, difficulties of phasing are avoided.

Both this and the Bellini system may therefore be considered as two different methods of avoiding the necessity of mechanically rotating a large and comparatively heavy loop at a speed suitable for practical searching. But, whereas the former method only eliminates the factor of speed—for the loop still has to be rotatable—the latter reduces the only moving parts to extremely small dimensions. Something must move, and in the Bellini exploring coil we have this unavoidable residuum reduced to instrument size, and the world-field (as it were) brought to a focus upon it by the motionless external system. There is no limit to the dimensions of this system. On page 271, section (2), the author hints that the proportionality of E.M.F. to ampere turns may not be indefinitely true, and without plunging too deeply into a matter still awaiting experimental evidence, it seems likely that this is so, and that the few or single turn loop, having a much greater phase-difference between its extreme dimensions, is an arrangement superior to the small multiple coil.

For all these reasons the Bellini system seems to be the most complete basic solution of the directional problem ever proposed.

There remains now to be discussed only the one other factor of Captain Robinson's system—the superimposed constant signal.

By what has already been shown, this signal takes no part in the direction-determination. It is not a technical, but a human or psychological factor. It is often convenient that the operator should be able to hear and read the signal during the whole period of searching ; though, in peace time, when no tactical reasons exist for cutting this down to the limit of brevity, it does not seem a very great matter. Even on a radiogoniometer the signal is not really lost while the reading is being made.

More important is the claim that the human ear can more easily judge the relative strength of signals which succeed each other rapidly without passing through silence. This depends entirely upon the personality of the actual operator. The present writer remembers in 1919 interrogating some officers with long experience in direction-finding work on their personal preferences ; and the general opinion was in favour of the radiogoniometer method. He cannot but think, however, that there is some basis for this claim.

Even supposing this factor to be of importance, it must not be forgotten that, unless the whole of the present analysis is false, this constant-signal arrangement can be applied to any direction-finding system, and can equally well be quite independent of any of the apparatus or circuits used in the actual determination of direction.

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Let us turn now to the application of direction-finding to aircraft—p. 267, section (6).

It will be seen from the author's lucid explanation that there are two methods of applying his system to an aeroplane, which may be briefly described as (1) fixed coils, and the turning of the aeroplane in the world-field; (2) coils movable in the world-field and rotatable with respect to the machine.

(1) This is the only arrangement possible on small machines where there is no room for the larger apparatus. It is satisfactory only for flying direct on to a signal. It is not very practicable for taking bearings, for the machine has to be turned off its course, by an *amount not apparent to the pilot* unless he is also the operator, which change of course is not very welcome to the navigator. This is slow, and has to be done twice to get a cross-bearing; and in each case the compass has to be read immediately after a change of course. For many such reasons its use is limited.

(2) This is only applicable to the larger machines where there is room for movable coils of adequate size, but under these conditions it is a practical system exhibiting all the virtues and defects of the particular method discussed.

But it must not be assumed that aircraft direction-finding stands or falls by either of these methods. It is perfectly practicable to apply the Bellini method to aeroplanes by stringing a pair of single wire loops on the plane, with very successful results; and such an installation will have the virtues which have been discussed in the present paper.

Such an installation was installed by the Marconi Company in the Handley Page machine which was intended for the trans-Atlantic flight. Until this machine was crashed it was navigated with the utmost success by means of it, and it is a record that signals from the English side were picked up at once and determined to within one degree as soon as the machine got into the air at Newfoundland.

In conclusion, although his particular system has been criticised from a technical point of view, the present writer is very much aware of the great services rendered by Captain Robinson to wireless aerial navigation during the war. Making this subject his own, his whole-hearted devotion to it was the means of raising the art (in so far as it related to direction-finding on the machine) to a level of great importance and of instituting a valuable organisation. Only now that peace has given more leisure for the study of the problem, it is necessary to search for the true line of advance, and not to be led aside into unfertile regions.

Under peace conditions the balance of argument is strongly in favour of position finding from ground stations, but for war purposes, or under certain particular circumstances, there is undoubtedly a field for direction-finding from the machine.

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A Theory of the Amplitude of Free and Forced Triode Vibrations.

By BALTH. van der POL, Jun., D.Sc.

INTRODUCTION.

The conditions to be fulfilled by a circuit linked to a triode in order to generate oscillations have been fully treated by several writers. Their differential equations were mostly confined however to the linear terms and in consequence could be satisfied by any amplitude whatever, though implicitly these differential equations are only valid for infinitesimal oscillations.

As a given triode oscillator, with definite settings of the circuit constants, will generate oscillatory currents with harmonics all having a definite amplitude, it may be worth while to put forward a theory of the oscillating triode having regard to the non-linear terms in the equations. Only in this way can certain properties of a triode system be explained which would otherwise escape the analytical treatment, such as the rectifying action, the interaction of two oscillatory systems, the function of a thermionic bulb as a limiter of amplitude, the working of the heterodyne, the greater magnifications given to small impressed E.M.F.'s than to bigger ones, the generation of higher harmonics, etc.

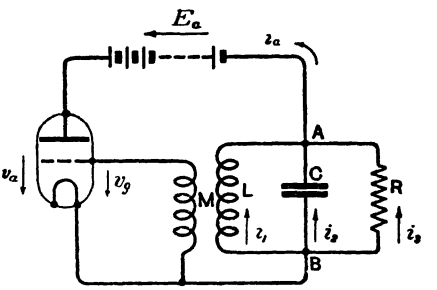

FIG. 1.

When the non-linear terms are retained in the equations the latter, and still more their solutions, soon become very complicated and in order to show clearly and definitely the importance of these terms it seems advisable to treat analytically that system of connections which renders the equations as simple as possible, thus obviating as far as possible, purely analytical complications, and allowing the physical meaning of the formulæ to be clearly seen. This is especially the case in locating the resistance of the oscillatory L C flywheel circuit connected to the anode and filament, not in series either with the self-inductance or capacitance but in parallel to both.

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I.—The Triode as a Generator of Oscillations.

1. Let, as indicated in Fig. 1

i_1 be the total current in the self-inductance branch L.

i_2 be the total current in the capacity branch C.

i_3 be the total current in the resistance branch R.

$i_a = i_1 + i_2 + i_3$ be the total anode current.

E_a the E.M.F. of the anode battery.

v_a the plate potential difference
v_g the grid potential difference } with respect to the filament

then we have

$$L\frac{di_1}{dt} = Ri_3 = \frac{1}{C}\int i_2 dt = E_a - v_a$$

$$M\frac{di_1}{dt} = v_g$$

where M is chosen positive when it has the proper sense to generate oscillations. Eliminating i_1, i_2 and i_3 we arrive at the simple equation:

$$\frac{di_a}{dt} + \left(\frac{1}{L} + \frac{1}{R}\frac{d}{dt} + C\frac{d^2}{dt^2}\right)(v_a - E_a) = 0 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where the grid currents are neglected.

Let further the anode current i_a be a function ϕ of the *single* variable $v_a + gv_g$ (called the "lumped voltage" *) where g is the "voltage ratio" of the tube. Hence

$$i_a = \phi(v_a + gv_g) = \phi\left\{v_a + g\frac{M}{L}(E_a - v_a)\right\} \quad . \quad . \quad . \quad (2)$$

In the steady, though unstable, state $v_{a_0} = E_a$ as there is no potential drop in the resistanceless branch L. The steady (unstable) anode current we call i_{a_0}; obviously

$$i_{a_0} = \phi(v_{a_0}) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

If v be the momentary deviations of the plate potential from the unstable value E_a we have $v_a - v_{a_0} = v$, and the total anode current becomes:

$$i_a = \phi\left\{v_{a_0} - \left(g\frac{M}{L} - 1\right)v\right\}$$

or

$$i_a = \phi(v_{a_0} - kv) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where $$k = \left(g\frac{M}{L} - 1\right)$$

* W. H. Eccles, Radio Review, 1, p. 73, November, 1919.

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If i be the instantaneous deviations of the total plate current i_a from the unstable value i_{a_0}, we have

$$i = i_a - i_{a_0} = \phi(v_{a_0} - kv) - \phi(v_{a_0}) \quad . \quad . \quad . \quad . \quad . \quad (5)$$

which may be written

$$i = \psi(kv) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The fundamental equations of the triode oscillator are therefore

$$\left.\begin{aligned} \frac{di}{dt} + C\frac{d^2v}{dt^2} + \frac{1}{R}\frac{dv}{dt} + \frac{1}{L}v = 0 \\ i = \psi(kv) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (\text{I.}^{a,b})$$

2. Before proceeding we will first consider the functions ϕ and ψ.

The steady characteristic $i_a = \phi(E_a)$ has the well-known form of Fig. 2. From this characteristic the one of Fig. 3 can readily be derived where i is represented as $i = \psi(kv) = \phi(v_{a_0} - kv) - \phi(v_{a_0})$.

In the latter figure this function has been drawn for the values $k = -1, \frac{1}{2}, 1$ while for $k = 0$, $\psi(kv)$ coincides with the axis of abscissæ.

From this figure, which may be said to represent a family of "derived" characteristics, it is clear that the "falling" characteristic necessary for the generation of oscillations is only obtained when $k > 0$, *i.e.*, for

$$g\frac{M}{L} > 1.$$

In the second part of this paper it will be shown more fully that, if $k = 0$, *i.e.*, $g\frac{M}{L} = 1$, the "resistance" brought into the circuit by the presence of the triode is just compensated for by its regenerative action.

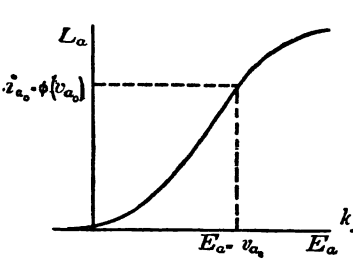

FIG. 2.

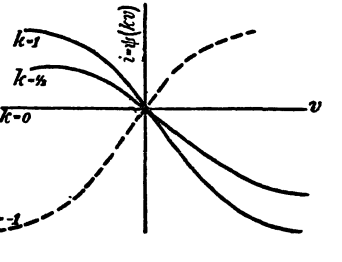

FIG. 3.

3. Taking up the analysis again, we see from (2), (4) and (5) that if we assume that the curves in Fig. 3 can be represented by the equation

$$i = \psi(kv) = -\alpha v + \beta v^2 + \gamma v^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

then by Maclaurin's theorem,

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$$\left.\begin{aligned} \alpha &= k\left(\frac{\partial i_a}{\partial v_a}\right)_{v_a = E_a} \\ \beta &= \frac{k^2}{2}\left(\frac{\partial^2 i_a}{\partial v_a^2}\right)_{v_a = E_a} \\ \gamma &= -\frac{k^3}{6}\left(\frac{\partial^3 i_a}{\partial v_a^3}\right)_{v_a = E_a.} \end{aligned}\right\} \quad \ldots\ldots\ (8)$$

where α and γ may be taken positive as long as $k > 0$. If $E_a = v_{a_0}$ is chosen such that i_{a_0} is just half the saturation value while the characteristic is considered symmetrical with regard to the point (v_{a_0}, i_{a_0}), β will vanish and (I.[a, b]) will be reduced to

$$C\frac{d^2v}{dt^2} + \left(\frac{1}{R} - \alpha\right)\frac{dv}{dt} + \frac{1}{L}v + \beta\frac{d(v^2)}{dt} + \gamma\frac{d(v^3)}{dt} = 0 \quad \ldots \quad \text{(II.)}$$

If our considerations are limited to small oscillations only, both γ and β may be neglected, thus leaving a linear equation with the condition for the generation of an alternating current, that

$$\frac{1}{R} - \alpha = 0.$$

With

$$\left(\frac{\partial i_a}{\partial v_a}\right)_{v_a = E_a} = h_a = \frac{\alpha}{k},$$

$$\left(\frac{\partial i_a}{\partial v_g}\right)_{v_g = 0} = h_g,$$

and

$$g = \frac{h_g}{h_a},$$

this amounts to

$$g\frac{M}{L} - 1 = \frac{1}{Rh_a} \quad \ldots\ldots\ (9)$$

However, with M greater than the value given by (9) the coefficient of $\frac{dv}{dt}$ in II. becomes negative and the oscillations would build up indefinitely were it not for the presence of the non-linear terms (with γ and β) in II. which put a limit to this increase, or, speaking geometrically: it is the curvature of the characteristic which determines the final amplitude.

4. First Method of finding the Amplitude of the Fundamental. Our equation II. is closely related to some problems which arise in the analytical treatment of the perturbations of planets by other planets, and of the vibrations of bodies not obeying Hooke's law, upon which Helmholtz's well-known theory of combination tones was based. Hence a somewhat similar way of solving II. may be applied here.*

* In this paragraph we follow closely a method of solution given by Prof. Lorentz in a series of lectures at Leiden University.

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Rewriting II. as:

$$\left(\frac{d^2}{dt^2}+\frac{1}{CL}-\epsilon\right)v+\left\{\epsilon+\left(\frac{1}{CR}-\frac{\alpha}{C}\right)\frac{d}{dt}\right\}v+\frac{\beta}{C}\frac{d(v^2)}{dt}+\frac{\gamma}{C}\frac{d(v^3)}{dt}=0 \quad . \quad (10)$$

we introduce a first order correction ϵ to the square of the natural angular frequency ω^2 by putting

$$\omega^2=\frac{1}{CL}-\epsilon \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

instead of

$$\omega^2=\frac{1}{CL}$$

Since the voltage is the sum of the fundamental and the various harmonics, we put

$$v=v_1+v_2+v_3+\ldots \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

and assume that this series converges, v_1 having the fundamental frequency, v_2 being the first overtone, v_3 the second, etc. Moreover v_1 will be taken to be of the first order of magnitude, v_2 of the second, v_3 of the third, etc.

Putting (12) in (10) we obtain an equation with several terms of different orders of magnitude.

Now equating to zero the sum of all terms of the first order, the sum of all terms of the second order, also of the third order, and limiting ourselves to terms of the third order, it would be impossible to get a solution unless we also assumed $\left\{\left(\frac{1}{CR}-\frac{\alpha}{C}\right)\frac{d}{dt}+\epsilon\right\}$ to be of the second order. With this assumption the following equations are obtained:

$$\left(\frac{d^2}{dt^2}+\frac{1}{CL}-\epsilon\right)v_1=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

$$\left(\frac{d^2}{dt^2}+\frac{1}{CL}-\epsilon\right)v_2=-\frac{\beta}{C}\frac{d}{dt}(v_1^2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

$$\left(\frac{d^2}{dt^2}+\frac{1}{CL}-\epsilon\right)v_3=-\left\{\epsilon+\left(\frac{1}{CR}-\frac{\alpha}{C}\right)\frac{d}{dt}\right\}v_1-\frac{2\beta}{C}\frac{d(v_1v_2)}{dt}-$$
$$-\frac{\gamma}{C}\frac{d(v_1^3)}{dt} \quad . \quad . \quad . \quad . \quad (15)$$

From (13) which is an equation of free oscillations we have

$$v_1=a\cos\omega t \quad \text{with } \omega^2=\frac{1}{CL}-\epsilon \quad . \quad . \quad . \quad . \quad . \quad (16)$$

where a is the unknown amplitude and ω the unknown angular frequency. Equation (14), representing a forced vibration of period 2ω, yields with (16)

$$v_2=-\frac{a^2\beta}{3C\omega}\sin 2\omega t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Equation (15) represents a forced vibration of periods ω and 3ω. In

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order to make sure that v_3 shall only contain terms of the frequency 3ω that part of the impressed E.M.F. in (15) having the frequency ω may now be put equal to zero, thus yielding two equations for the frequency correction ϵ and the fundamental amplitude a.*

We thus find from (15):

$$\left\{\epsilon + \left(\frac{1}{CR} - \frac{\alpha}{C}\right)\frac{d}{dt}\right\} a\cos\omega t + \frac{2\beta}{C}\frac{d}{dt}\left(-\frac{a^3\beta}{6C\omega}\sin\omega t\right) + \frac{\gamma}{C}\frac{d}{dt}\left(\frac{3}{4}a^3\cos\omega t\right) \equiv 0 \quad . \quad . \quad . \quad . \quad . \quad (18)$$

which must be satisfied at any moment. Hence we obtain for the frequency correction

$$\epsilon = \frac{a^2\beta^2}{3C^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

and for the square of the amplitude of the fundamental

$$a^2 = \frac{4}{3\gamma}\left(\alpha - \frac{1}{R}\right) \quad . \quad . \quad . \quad . \quad . \quad (20)$$

Finally, after solving also v_3, the solution of II. is:

$$v = a\cos\omega t - \frac{a^2\beta}{3C\omega}\sin 2\omega t + a^3\left(\frac{\beta^2}{8\omega^2C^2}\cos 3\omega t + \frac{3\gamma}{32\omega C}\sin 3\omega t\right) \quad . \quad . \quad (21)$$

while i contains the steady component $\frac{1}{2}a^2\beta$ which is the shift of the indication of a direct current milliamperemeter in the anode circuit, observed when the system starts generating oscillations.

A steady component does not occur in v which is obvious from the fact that one branch (L) has no resistance.

5. Second Method of finding the Amplitude of the Fundamental.

Instead of finding a solution v which at any moment satisfies (I.^{a,b}) we may from (I.^{a,b}) first derive several energy equations.

Integrating one such equation over the fundamental period gives an equation out of which the time t has disappeared. Next we try to find a quadratic mean value of v satisfying this mean energy equation and thus obtain the value of the amplitude a.

Very suitable for this way of treating the problem is the equation obtained by multiplying (I.^{a}) by $\int v dt$ and then integrating the result over the unknown fundamental period T.

Integrating by parts yields us the simple energy-equation (the other terms vanishing)

$$\int_0^T i v dt + \frac{1}{R}\int_0^T v^2 dt = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

* If those terms in the second member of (15) which contain the frequency ω were not identified with zero, so called "secular terms" in v_3 would be necessary (of the form $t\sin\omega t$) which would disturb the purely periodical character of our solution.

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We now assume as a first approximation that v varies sinusoidally, hence

$$v = a \cos \omega t$$

$$\therefore \quad \frac{1}{T}\int_0^T v^2 dt = \frac{a^2}{2}$$

Further

$$iv = -\alpha v^2 + \beta v^3 + \gamma v^4$$

yielding

$$\frac{1}{T}\int_0^T iv dt = -\frac{\alpha}{2} a^2 + \frac{3}{8}\gamma a^4.$$

Putting these results in (22) we at once obtain the square of the amplitude:

$$a^2 = \frac{4}{3}\frac{\alpha - \frac{1}{R}}{\gamma}$$

which equals (20) found above.

The assumption (in order to find the amplitude) of v having an accurately sinusoidal form may be justified by the following considerations.

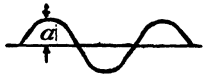

FIG. 4.

FIG. 5.

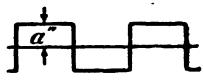

FIG. 6.

If v is assumed to have the form of Fig. 5 with maximum elongation a', the mean quadratic value of v is found from (22) to be

$$a'^2 = \frac{5}{3}\frac{\alpha - \frac{1}{R}}{\gamma}$$

while the fundamental harmonic component a is related to a' by the equation

$$a = \frac{8}{\pi^2} a'.$$

Hence for the waveform of Fig. 5 we find

$$a^2 = \frac{64}{\pi^4} \cdot \frac{5}{3}\frac{\alpha - \frac{1}{R}}{\gamma} = 1{\cdot}095\frac{\alpha - \frac{1}{R}}{\gamma}$$

or

$$a = 1{\cdot}047\frac{\alpha - \frac{1}{R}}{\gamma}.$$

For the widely different waveform of Fig. 6 with maximum elongation a'', we find in a similar way

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$$a''^2 = \frac{\alpha - \frac{1}{R}}{\gamma}$$

$$a = \frac{4}{\pi} a''$$

$$\therefore a^2 = \frac{16}{\pi^2} \frac{\alpha - \frac{1}{R}}{\gamma} = 1{\cdot}620 \frac{\alpha - \frac{1}{R}}{\gamma}$$

or $$a = 1{\cdot}274 \frac{\alpha - \frac{1}{R}}{\gamma}.$$

Taking the mean of the two a's from Fig. 5 and Fig. 6 we find a value that differs less than a half of one per cent. from the value of a obtained from the sinusoidal wave form, namely

$$a = 1{\cdot}155 \frac{\alpha - \frac{1}{R}}{\gamma}.$$

Hence we see that the extreme forms of Fig. 5 and Fig. 6 yield amplitudes for the fundamental frequency of v of values only slightly different from the one obtained on the basis of the purely sinusoidal v, and we may accept the result

$$a^2 = \frac{4}{3} \frac{\alpha - \frac{1}{R}}{\gamma} \quad \ldots\ldots\ldots \quad (20)$$

with confidence.

6. Discussion of results so far obtained.—Formula (20) only leads to a stable oscillation with real amplitude when, for $\gamma > 0$, $\alpha > \frac{1}{R}$, *i.e.*, for

$$\left(g\frac{M}{L} - 1\right) > \frac{1}{Rh_a}$$

a^2 would also be positive for both $\gamma < 0$ and $\alpha - \frac{1}{R} < 0$. However the oscillations set up in this case are unstable * so that this case can further be excluded from our physical considerations.

The damping factor of the L C R circuit of Fig. 1 (see also Fig. 7) but disconnected from the triode, is well known to be $\frac{1}{2CR}$. Hence the smaller the shunt resistance the more the natural oscillations of the circuit L C R

* Rayleigh, *Philosophical Magazine*, April, 1883.

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will be damped. Similarly the damping factor of a circuit consisting of L, C and r *in series*, is $\frac{r}{2L}$.

If therefore the latter circuit were connected to the triode, we can, with the accuracy obtained in the above analysis, simply replace $\frac{1}{R}$ by $\frac{Cr}{L}$ and hence obtain for the amplitude of oscillations of such a series resistance circuit

$$a^2 = \frac{4}{3}\frac{\alpha - \frac{Cr}{L}}{\gamma}.$$

The same formula will be found if, *ab initio*, we start formulating the differential equations for the case of a series resistance r. The analysis however is much more complicated.

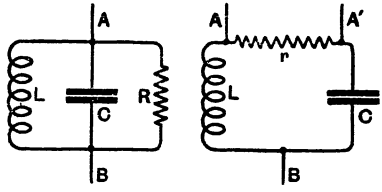

FIG. 7.

As a first approximation it does not matter whether the plate is connected at A or A′ (Fig. 7), whether therefore the resistance r is in the L or the C branch. For the sake of simplicity we shall discuss our further results, with the *parallel* resistance R, keeping in mind that the *smaller* is R, the *more* the system is damped.

From (19) and (20) it follows that the frequency correction ϵ, as might be expected, is a function of the amplitude, but also of β, *i.e.*, of $\frac{\partial^2 i_a}{\partial v_a^2}$, whereas the amplitude, as a first approximation, is not affected by the magnitude of β, but only depends upon α and γ, *i.e.*, upon $\frac{\partial i_a}{\partial v_a}$ and $\frac{\partial^3 i_a}{\partial v_a^3}$.

This dependence of the frequency upon the part of the characteristic where the triode is functioning may be illustrated by the following experiment.

It is well known that only with the utmost care can such a small correction experimentally be made evident by altering *e.g.* the grid potential by means of a potentiometer arrangement, as the slightest alteration of the circuits materially affects the tuning conditions. Hence it appears a better course to let the triode itself bring its oscillations on a different part of its characteristic. To this end it is only necessary, instead of connecting the grid directly to the grid coupling coil of M, to insert at this place a large condenser of say 1 μF.

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If the insulating quality of this condenser is not extreme, oscillations will be set up which gradually die down owing to the negative charge accumulating on the grid, the latter thus acquiring a gradually increasing negative potential. After some time (occasionally twenty seconds) the system will suddenly again burst into oscillations and the same phenomena will occur over and over again. If in another (autodyne) system one listens to this phenomena, the audible combination tone is very distinctly heard to alter its pitch during the time the first system oscillates, thus proving clearly the gradual fall of frequency when a triode system vibrates lower down on its characteristic.

The Capacity of Rectangular Plates and a Suggested Formula for the Capacity of Aerials.

By THE EDITOR.

The capacity of any conducting body, whatever its shape, can be determined by the method devised by the author for the calculation of the capacity of multiple wire antennæ. A uniform distribution of charge over the surface is assumed and the average potential calculated; the uniform potential actually obtained when the same total charge is allowed to have its natural distribution will approximate very closely to this average potential. Formulæ can be established for the value of the average potential over surfaces of

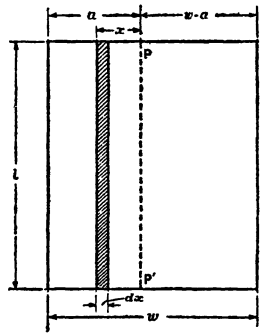

FIG. 1.

simple geometrical form which greatly simplify the calculation. The author has also shown that the same method and formulæ can be used to calculate the resistance to earth of any system of buried conductors. In working out the original formulæ it was assumed that the conductors consisted of round wires, which is of course usually the case with aerials, but in the case of buried conductors copper strip is often employed and the formulæ for round wire cannot be applied. It is, moreover, often necessary to determine approximately the capacity of rectangular plates.

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Let a rectangular plate l cms. long and w cms. wide (Fig. 1) have a uniform charge of 1 unit per sq. cm., then the average potential along the line PP' due to the charge on the strip $l.dx$ at a distance x from PP' is given by the formula*

$$\delta V_P = 2\left(\sinh^{-1}\frac{l}{x} + \frac{x}{l} - \sqrt{1+\frac{x^2}{l^2}}\right)dx.$$

The average potential along the line PP' due to the whole plate will be

$$V_P = \int_0^a + \int_0^{w-a} 2\left(\sinh^{-1}\frac{l}{x} + \frac{x}{l} - \sqrt{1+\frac{x^2}{l^2}}\right)dx$$

now

$$\int \sinh^{-1}\frac{l}{x}\,dx = x\sinh^{-1}\frac{l}{x} + l\sinh^{-1}\frac{x}{l}$$

$$\int \frac{x\,dx}{l} = \frac{x^2}{2l}$$

and

$$\int \sqrt{1+\frac{x^2}{l^2}}\,dx = \frac{x}{2l}\sqrt{l^2+x^2} + \frac{l}{2}\sinh^{-1}\frac{x}{l}.$$

Hence the average potential along PP' will be

$$V_P = 2\left[x\sinh^{-1}\frac{l}{x} + \frac{l}{2}\sinh^{-1}\frac{x}{l} + \frac{x^2}{2l} - \frac{x}{2l}\sqrt{l^2+x^2}\right]_0^a + \ldots\Big]_0^{w-a}$$

$$= 2\left(a\sinh^{-1}\frac{l}{a} + \frac{l}{2}\sinh^{-1}\frac{a}{l} + \frac{a^2}{2l} - \frac{a}{2l}\sqrt{l^2+a^2}\right)$$

+ a similar expression with $w-a$ instead of a.

The average potential over the whole plate will be

$$V = \frac{1}{w}\int_0^w V_P\,da$$

$$= \frac{2}{w}\int_0^w \left(2a\sinh^{-1}\frac{l}{a} + l\sinh^{-1}\frac{a}{l} + \frac{a^2}{l} - \frac{a}{l}\sqrt{l^2+a^2}\right)da$$

$$= \frac{2}{w}\Bigg[\left(a^2\sinh^{-1}\frac{l}{a} + l\sqrt{a^2+l^2}\right) + l\left(a\sinh^{-1}\frac{a}{l} - \sqrt{a^2+l^2}\right) +$$

$$+ \frac{a^3}{3l} - \frac{(a^2+l^2)^{\frac{3}{2}}}{3l}\Bigg]_0^w$$

* See *Electrician*, 73, p. 859, September, 1914.

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$$= 2w \sinh^{-1}\frac{l}{w} + 2l \sinh^{-1}\frac{w}{l} + \frac{2}{3}\frac{w^3 + l^3 - (w^2 + l^2)^{\frac{3}{2}}}{wl}$$

Area of the plate $= wl$ and therefore the charge $Q = wl$ units.
Let

$$\alpha = \frac{l}{w} \quad \text{then } Q = wl = \frac{l^2}{\alpha}$$

For the capacity we have

$$C = \frac{Q}{V} = \frac{l^2}{\alpha V} \text{ cms.}$$

Putting $w = l/\alpha$ in the above formula for V we have

$$C = \frac{l^2}{2\alpha\left\{\frac{l}{\alpha}\sinh^{-1}\alpha + l\sinh^{-1}\frac{1}{\alpha} + \frac{\alpha^3 + 1 - (\alpha^2+1)^{\frac{3}{2}}}{3\alpha^2}l\right\}} \text{ cms.}$$

$$= \frac{\sqrt{wl}}{2\sqrt{\alpha}\left\{\frac{\sinh^{-1}\alpha}{\alpha} + \sinh^{-1}\frac{1}{\alpha} + \frac{\alpha}{3} + \frac{1}{3\alpha^2} - \frac{(\alpha^2+1)^{\frac{3}{2}}}{3\alpha^2}\right\}} \text{ cms.}$$

$$= k\sqrt{wl} \text{ centimetres}$$

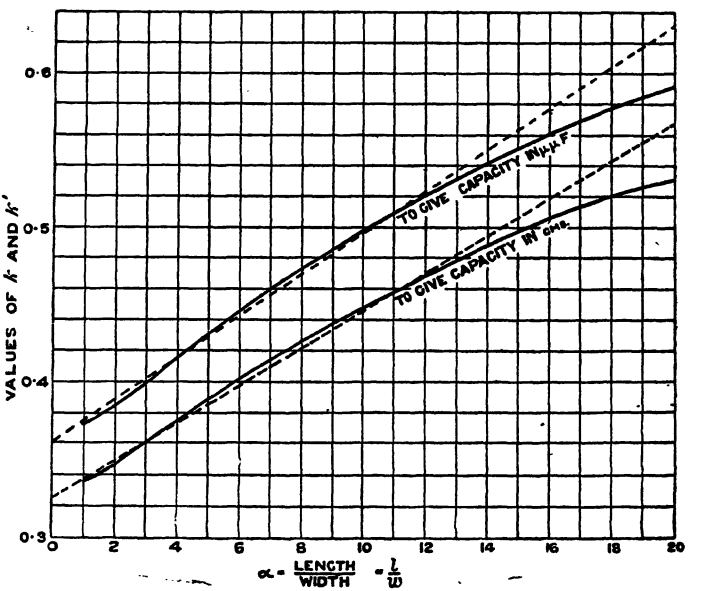

FIG. 2.

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where k is a coefficient depending only on α. The values of k for a number of values of α are given in Table I. For intermediate values they can be read off the lower curve in Fig. 2. To obtain the capacity in micro-micro-farads the above values must be divided by 0·9 (upper curve in Fig. 2).

TABLE I.

$a =$	1	2	3	4	5	10	20
$k =$	0·336	0·346	0·360	0·374	0·388	0·448	0·532
$\frac{k}{0·9} =$	0·373	0·384	0·400	0·415	0·431	0·498	0·591

From the dotted straight lines in Fig. 2 it is seen that the value of k is given approximately by the equation

$$k = 0·324\,(1 + 0·0375\alpha).$$

This is applicable for ratios of length to width up to 12 or 14.

It is of interest to compare this with an empirical result obtained by Austin from the measured capacity of multiple wire rectangular aerials,* viz.

$$C = \left(4\sqrt{a} + 0·885\frac{a}{h}\right)\left(1 + 0·015\frac{l}{w}\right) \times 10^{-5} \text{ microfarads}$$

where a is the area in square metres and h is the height in metres.

Adopting these units and nomenclature our calculated formula becomes

$$C = 3·6\sqrt{a}\,.\left(1 + 0·0375\frac{l}{w}\right) \times 10^{-5} \text{ microfarads.}$$

Austin's formula is only applicable if the aerial wires are closely spaced, and in this case, as we have already shown,† the capacity approximates closely to that of a whole surface.

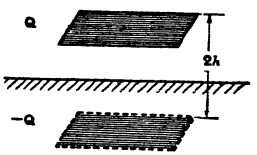

FIG. 3.

The other term in Austin's formula is due to the proximity of the earth. This may be calculated by finding the effect on the potential of the aerial of its image in the earth. If the area of the plate or aerial is small compared with the height, little error is made in assuming that the potential of the

* *Proceedings Institute of Radio Engineers*, 8, p. 164, April, 1920.
† *Electrician*, 73, p. 861, Fig. 15, September, 1914.

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aerial due to the charge on its image is $-\frac{Q}{2h}$. It will in fact be slightly less because $2h$ is the minimum distance between the two charges (Fig. 3).

Ignoring the effect of the earth, we have seen that the calculated capacity may be written

$$C = k\sqrt{wl} \text{ cms.}$$

and therefore

$$V = \frac{Q}{C} = \frac{wl}{k\sqrt{wl}} = \frac{\sqrt{wl}}{k}.$$

The presence of the earth reduces the potential to

$$\frac{\sqrt{wl}}{k} - \frac{wl}{2h} = \frac{\sqrt{wl}}{k}\left(1 - \frac{k\sqrt{wl}}{2h}\right).$$

The quantity in brackets is the ratio in which the potential is reduced and therefore its reciprocal is the ratio in which the capacity is increased. If $\frac{k\sqrt{wl}}{2h}$ is small compared with unity, this reciprocal is approximately $1 + \frac{k\sqrt{wl}}{2h}$.

The total capacity is therefore

$$C = k\sqrt{wl}\left(1 + \frac{k\sqrt{wl}}{2h}\right) \text{ cms.}$$

Putting in the approximate linear equation for k, viz.,

$$k = 0{\cdot}324\ (1 + 0{\cdot}0375\alpha),$$

we have

$$C = \left(1 + 0{\cdot}0375\alpha\right)\left(0{\cdot}324\sqrt{wl} + \frac{0{\cdot}105\ (1 + 0{\cdot}0375\alpha)\ wl}{2h}\right) \text{cms.}$$

$$= \left(1 + 0{\cdot}0375\alpha\right)\left(0{\cdot}324\sqrt{wl} + 0{\cdot}0525\frac{wl}{h}\ (1 + 0{\cdot}0375\alpha)\right) \text{cms.}$$

All the dimensions and the capacity are in cms. With Dr. Austin's units and nomenclature our formula becomes

$$C = \left\{3{\cdot}6\sqrt{a} + 0{\cdot}58\frac{a}{h}\left(1 + 0{\cdot}0375\frac{l}{w}\right)\right\}\left(1 + 0{\cdot}0375\frac{l}{w}\right) \times 10^{-5} \text{ microfds.}$$

This involves a slight difference from the form of Dr. Austin's equation, but the effect of the additional factor may be too small to be detected by measurements on aerials. In view of the difficulty of making due allowance for various disturbing factors, such as down leads, masts, stays, etc., such measurements cannot be made with a high degree of accuracy. The following examples illustrate, however, the close agreement between the theoretical and the experimental formulæ. If $l/w = 5$, Austin's formula is $4{\cdot}3\sqrt{a} + 0{\cdot}95\ a/h$, whilst ours is $4{\cdot}27\sqrt{a} + 0{\cdot}816\ a/h$; if $l/w = 10$, Austin's formula is $4{\cdot}6\sqrt{a} + 1{\cdot}02\ a/h$, and ours $4{\cdot}95\sqrt{a} + 1{\cdot}095\ a/h$.

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Multiplex Telephony and Telegraphy using High Frequency Currents (Wired Wireless).*

By K. W. WAGNER.

A year ago the author read a paper † on the same subject in which he considered its historical, theoretical and technical aspects, and referred to successful experiments that had been made. In the present paper he gives an account of practical tests under working conditions carried out by the German Telegraph Department during the past year.

I. MULTIPLEX TELEPHONY.

In the beginning of 1919 three simultaneous conversations were carried out on a 3 mm. bronze line between Berlin and Hanover (300 km.). This was done under practical working conditions, that is to say, any subscriber in Berlin was connected through from the local to the main exchange and then made use of the high-frequency service to Hanover where the connection to the desired subscriber was completed. Although successful several months' work was required to overcome the gap between experimental success with the apparatus under the watchful care of physicists and engineers and the installation of apparatus which would stand the ordinary conditions of service in the hands of less trained *personnel.* It was essential that the apparatus should be simple to operate and, in view of the present cost of labour, that it should be as automatic as possible. At the same time the cost of upkeep and of renewals must be kept as low as possible.

In addition to these general requirements, it was essential in the present case that the high-frequency connection should be made and controlled by the operator in exactly the same way as the ordinary line connection. For example, it must be made impossible for two operators to attempt to use any high-frequency connection at the same time.

It was also essential that in case of breakdown or trouble of any kind the attendants in the high-frequency rooms at Berlin and Hanover could communicate without the provision of a new line and that the necessary switching to make this connection should be as simple and rapid as possible.

At the beginning of October, 1919, the triple connection on the Berlin-Hanover wire was ready for service. From that time it has been in daily use for eight to ten hours with complete satisfaction. Each of the three sets handle up to 120 conversations of three minutes duration per day. The articulation leaves nothing to be desired; the loudness has been adjusted to equality with the ordinary connection, corresponding to $\beta l = 1{\cdot}3$, that is, it reaches a high standard. When, on account of noises due to imperfect earthing, ordinary telephony had to be interrupted, the high-frequency communication could still be carried on.

The high-frequency apparatus is in a special room, the separation being necessary to the organisation and operation of the exchange. The high-

* From a paper read before the Elektrotechnische Verein, Berlin, on May 18th, 1920.

† *Elektrotechnische Zeitschrift*, 40, p. 383, August 7th, and p. 394, August 14th, 1919.

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frequency room requires only a single official with a female assistant; even on changing over to another wire no fresh adjustment is required. The present *personnel* could control considerably more apparatus.

The system has also been tried under working conditions between Berlin and Frankfurt, a distance of 600 km.

The oscillation generator contains two 10-watt tubes and its frequency can be adjusted between 15,000 and 1,500,000. The receivers and three-stage amplifiers are of the ordinary type.

Although there is no fundamental difficulty in carrying ten or more conversations on one wire it was decided to perfect and thoroughly test the more modest attainment of three conversations on a single wire. From the results obtained there is no doubt that in high-frequency multiplex telephony a way has been found of considerably improving the position with respect to the need for further telephonic facilities.

II. MULTIPLEX TELEGRAPHY.

In many respects high-frequency telegraphy is simpler than the analogous telephonic problem, and although the decision to pass from the successful laboratory experiments to the practical application was taken later in the case of telegraphy, this was only because the need was not so great. In both cases the need was greatest on the main lines of communication and it was for that reason that tests were made on one of the principal routes, viz. Berlin-Frankfurt. The traffic is very heavy and is carried by double-current Siemens high-speed printers. In the high-frequency system the Siemens transmitter sends its positive and negative currents, not to the line, but to a relay, which connects and disconnects the high-frequency transmitter and the line. At the receiving end, the currents are amplified before passing to a thermionic relay (two double-grid tubes) which operates the double-current receiver. The high-frequency currents can be amplified, or a heterodyne can be employed and the beats amplified; both methods have been successfully employed. Such a system with two simultaneous messages has been working over the 600-km. line since January for eight to nine hours per day and handling up to 2,000 telegrams daily; this is about 30 per cent. of the total traffic between Berlin and Frankfurt. The high-frequency apparatus is in a separate room and in Berlin the high-frequency currents pass through 1 km. of ordinary telephone cable (0·8 mm.) to the telephone exchange where it passes to the telephone line. The line is used at the same time for telephony without any interference. The duplex working has since been replaced by six-fold telegraphy over a single line which is used at the same time for telephony. This is capable of handling 16,000 telegrams per day.

Satisfactory tests have also been made between Berlin and Magdeburg (150 km.) in the operation of Hughes apparatus over the telephone line, in a similar manner to that described above.

The author concludes by saying that the successful results obtained lead one to hope that high-frequency operation will help them in the difficult task of raising the telephonic and telegraphic facilities to their old standard.

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Review of Radio Literature.

1. Articles and Patents.

1042. The Theory of the Baretter. K. Küpfmüller. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 60—63, July, 1920.)

A mathematical proof that if the alternating current contain harmonics, a reversal of connections to the baretter wire will give a different reading. This is due to the temperature and resistance of the wire following the alternations of the current to some extent; the effect will therefore be less the higher the frequency. A case is quoted in which a difference of 1 per cent. was observed at a frequency of 800.

1043. Period and Decrement of an Oscillatory Circuit with a Short-circuited Secondary. I. Jones. (*Philosophical Magazine*, 39, pp. 553—565, May 1920. *Science Abstracts*, 23A, p. 400, Abstract No. 1007, July 31st, 1920—Abstract.)

This article gives a mathematical treatment of the oscillations in a primary circuit to which a short-circuited secondary is coupled. It is assumed that the secondary capacity is negligible and that its resistance may be varied. Calculation shows that the general effect upon damping of the oscillations caused by increasing R_2/L_2 with constant coupling, is an almost linear increase and that the frequency diminishes as R_2/L_2 increases, the diminution being more rapid the greater the value of the coupling. The decrement increases with the coupling and corresponding curves are given for the effects on the frequency. It is also shown that there is a limiting value of k^2 below which oscillations are set up for all values of R_2/L_2 and above which there is a range in which no oscillations are produced. This limiting value is 0·889. (k = Coupling coefficient. R_2 = Secondary resistance. L_2 = Secondary inductance.)

1044. Recent Experimental Work in Radiotelegraphy. F. Kiebitz. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 88—90, August, 1920.)

This is an interim report of the Telegraph Department. The following subjects are dealt with: The directive effect of bent aerials; in some cases no directive effect is found. A comparison of elevated and earth antenna. The action of the dry soil above the water level near the aerial. An attempt to show experimental and directive effect by means of the auxiliary aerial suggested by Abraham was not successful. Little if any connection could be traced between the atmospheric disturbances and the meteorological conditions. The permissible strength of a disturbing signal was investigated for different conditions as regards wavelengths and tones of the two sending stations. The variation of frequency of various C.W. stations was observed. Comparative tests are being made on high and low frequency amplifiers and also of separate and self-heterodyne systems. Wireless telephony tests are being carried on between Alt-Strelitz and Lärz to test various methods of modulation. A method has been devised for the measurement of very weak coupling. Experiments are being made for operating a Wheatstone high-speed receiver through a series of amplifiers and rectifiers.

1045. The Significance of Maxwell's Theory. A. Press. (*Electrician*, 85, pp. 177—178, August 13th, 1920.)

The author considers the longitudinal formation of a line of force at an infinite speed, in distinction of its lateral propagation at the speed of light, and criticises the interpretation usually placed upon the Maxwellian equations of wave propagation. In view of the circuital nature of all currents in the Maxwellian equations, it is maintained that the present theories of the space charge in triode valves require careful revision. It is stated that the author intends to return to the subject of wave propagation in a subsequent communication.

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1046. NOTE ON RADIO FREQUENCY MEASUREMENTS. C. Englund. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 326—333, August, 1920.)

Deals critically with the need for and design of a radio-frequency bridge suitable for general use. The methods developed for use at the Western Electric Co.'s Engineering Laboratory are briefly described. With frequencies up to 200,000 radio-frequency bridge measurements are not very troublesome but with 1,000,000 cycles the spacing and shielding of generator, bridge and detector are all-important. Shielding against electromagnetic induction has not proved successful in eliminating interference but electrostatic shields have been found quite successful.

The generator of the bridge scheme here advocated consists of a valve set, the negative end of the filament being earthed and the generator inductance unit being a toroidal coil. If no terminal of the bridge proper may be grounded two transformers for input and output are necessary while each section of the bridge is electrostatically shielded. The balance is observed by ear up to 10,000 cycles, but above this frequency the beat method with separate heterodyne oscillator is used and it is possible to balance much more accurately than is justified by the standards available. Air condensers with negligible dielectric losses (calibrated at low frequency) and resistances have been used as the basis of the work. Coils are tuned with such a condenser and measured as pure resistances. The so-called "shunt" capacity of a coil is determined by successively balancing the coil with the standard condenser at two frequencies. The "shunt" capacity C_0 may then be determined from the formula

$$C_0 = \frac{C_1 - \frac{\omega_2^2}{\omega_1^2} C_2}{\frac{\omega_2^2}{\omega_1^2} - 1}$$

where C_1 and C_2 are the balancing capacities at frequencies ω_1 and ω_2 respectively.

Absolute frequency determinations are made by bridging the gap from an audio frequency (tuning fork or siren) and the desired radio frequency by means of a valve oscillator with multiple harmonics. (See also RADIO REVIEW Abstract No. 1, October, 1919.)

1047. THE MEASUREMENT OF VERY SHORT TIME INTERVALS. P. E. Klopsteg. (*Physical Review*, 15, pp. 12—23, January, 1920. *Science Abstracts*, 23A, pp. 313—314, Abstract No. 792, June 30th, 1920—Abstract.)

For the determination of time intervals of the order of microseconds the method employed involves the determination of the potential difference of a condenser after it has been discharged for the interval of time to be measured. The particular novelty of the method described by the author lies in the use of a ballistic galvanometer in conjunction with a known potential difference or a potentiometer to determine the voltage of the condenser after discharge. The galvanometer deflection is due to the difference between the potential of the condenser and the comparison voltage and can therefore be made very small giving considerable accuracy.

1048. THE USE OF CONDENSERS IN HIGH-VOLTAGE MEASUREMENTS. A. Imhof. (*Bulletin of the Schweizische Elektrotechnische Verein*, 11, pp. 99—104, May, 1920. *Science Abstracts*, 23B, pp. 335—336, Abstract No. 659, July 31st, 1920. *Technical Review*, 6, p. 724, August 31st, 1920—Abstract.)

This paper investigates various arrangements of condensers for subdividing a high voltage for measurement purposes, and points out the errors that may arise and how they may be overcome.

1049. SPARK GAP. F. Lowenstein. (*French Patent* 500709, June 14th, 1919. Published March 23rd, 1920.)

The principal object is to provide a quenched spark gap of relatively simple construction,

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in which the component parts shall be individually movable and replaceable without dissembling the apparatus as a whole, and to provide easy means of adjustment. In one form the apparatus comprises a supporting plate of insulating material, a casing closed at one end by said plate, a plurality of tubular spark gap elements mounted in line with suitable apertures in said plate and electrically connected in series, a fan being arranged to move air through the casing to cool the gap elements. Each spark gap element comprises inner and outer conducting shells arranged co-axially, insulating rings spacing the shells apart to provide the spark gap, and ribs extending into the wider portions of the gap. A switch is provided to allow any number of spark gap elements to be connected in circuit.*

1050. Apparatus for Generating Oscillations. C. Lorenz. (*German Patent* 306495, August 22nd, 1917. Patent granted October 10th, 1919. Addition to German Patent 300777. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 503, June, 1920.)

An antenna excited by impulses from an electromagnetic buzzer circuit. See Fig. 1.

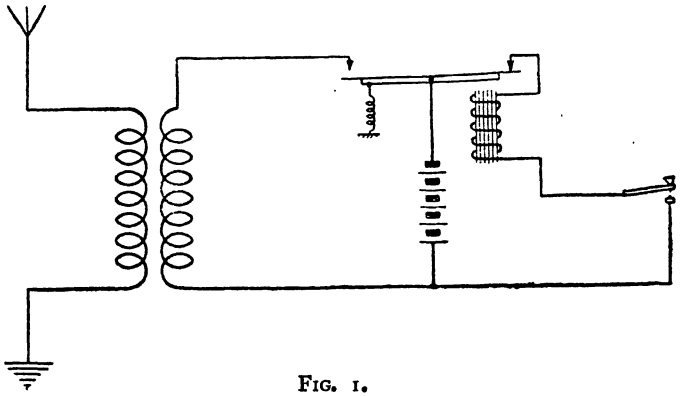

Fig. 1.

1051. Apparatus for Generating Oscillations. E. F. Huth and B. Rosenbaum. (*German Patent* 307191, June 1st, 1915. Patent granted October 6th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 492, June, 1920—Abstract.)

An arrangement for generating damped oscillations by an automatic electromagnetic contact breaker in which the self-induced "extra" E.M.F. of the electromagnet coil is used as charging voltage.

1052. Apparatus for Generation of Oscillations. Studien-Gesellschaft für Electrische Leuchtröhren. (*German Patent* 306317, November 3rd, 1917. Patent granted October 28th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 166, February, 1920—Abstract.)

A circuit in which the gap of a spark set transmitter is replaced by a discharge tube filled with one of the inert gases and provided with two electrodes of easily vaporisable metal.

1053. Continuous Wave Generator. Société Française Radio-Électrique. (*French Patent* 502160, March 20th, 1915. Published May 6th, 1920.)

The invention relates to the use of a mercury arc for the generation of electrical oscillations.

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* See also Radio Review Abstract No. 110, January, 1920.

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The arc is formed in a vacuum tube T (Fig. 2) between an anode A formed, for example, of graphite, and a cathode K of mercury. The arc is fed by a continuous current from X, while R is a resistance in series therewith. A particular point in the construction of the apparatus is a platinum point p fixed in the cathode and also an auxiliary arc with an anode B fed from a

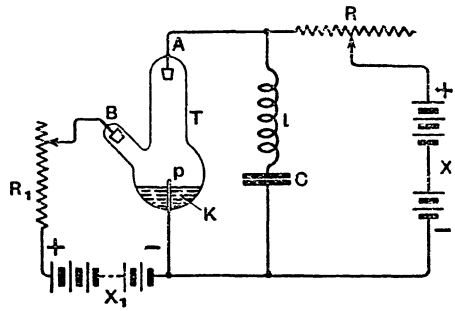

FIG. 2.

source X_1, through resistance R_1. The auxiliary arc forms a means of starting the main arc. To obtain the continuous waves an inductance L and a capacity C are connected across the main arc A, K.*

1054. ARC GENERATOR. O. Scheller and C. Lorenz Aktiengesellschaft. (*German Patent* 298973, May 28th, 1915. Patent granted October 9th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 171—172, February, 1920—Abstract.)

An arc generator of sustained waves in which the electrodes are not in the same straight line. The arc burns in a closed chamber and in a magnetic field.

1055. CONTINUOUS WAVE TRANSMITTER. Société Française Radio-Électrique. (*French Patent* 502639, December 8th, 1915. Published May 21st, 1920.)

The specification describes an arrangement of a mercury vapour tube for the production of continuous waves. For further particulars, see British Patent No. 126030.

1056. THE POULSEN ARC PLANT AT KÖNIGSWUSTERHAUSEN. H. Thurn. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 37—42, June, 1920; pp. 55—60, July, 1920. *Elektrotechnische Zeitschrift*, 41, pp. 686—687, September 2nd, 1920—Abstract.)

A description of the aerial (five masts 150 metres high) and of two arcs by Lorenz of Berlin supplying 32 kW and 5 kW respectively to the aerial. Of interest is a note to the effect that both electrodes are now of carbon and both rotate; they are not in line but at 90° forming an inverted V. It is stated that a method of sending is used in which by increasing the damping the aerial current is reduced to zero and the power taken by the arc greatly reduced in the spaces between the Morse signals. Photographs of the arcs and a diagram of connections are given. Various pieces of auxiliary apparatus are also described. The oscillation of the aerial is tested by a vacuum tube rotated at high speed in a darkened case.

A diagram of connections is given of a magnetically operated sending key relay and of a new type of wavemeter. The latter is shown in Fig. 3.

C_1 L_1 C_2 L_2 are connected in series, $C_1 = C_2$, but $L_1 = 2{\cdot}5\ L_2$. The instrument covers the range between the frequencies for which C_2L_2 and C_1L_1 respectively are in resonance. Hence

* See also *U.S. Patent* 1131190 (1910), by E. Weintraub, for a description of a very similar arrangement.

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as the frequency increases the impedance of C_1L_1 increases and that of C_2L_2 decreases, thus varying the ratio of the currents in the two fixed coils at right-angles and with it the position

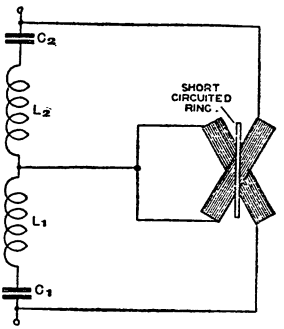

Fig. 3.

of the freely rotating copper ring turning within them. A pointer is attached to the spindle carrying the ring.

The article concludes with references to experiments in telephony, details of which cannot yet be published.

1057. High Frequency Alternator. Société Française Radio-Électrique. (*French Patent* 502604, September 16th, 1915. Published May 21st, 1920.)

The alternator is of the variable inductance type and the rotor and the stator are laminated in a direction parallel with the shaft, and comprise sets of plates forming teeth which are separated by non-magnetic material or by air gaps. The excitation and armature windings consist of coils concentric with the shaft and a single coil may serve both as excitation and as armature winding. A number of coils may be arranged on the stator with their sides displaced axially, which coils may be connected in parallel or series. For further particulars of this invention see British Patent No. 102738.

1058. Transmitter and Receiver for Wireless Telegraphy. Gesellschaft für drahtlose Telegraphie. (*German Patent* 310162, April 20th, 1918. Patent granted September 20th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 82, January, 1920—Abstract.)

A simple triode generating circuit with back-coupling in which the grid coil possesses inductance alone, so that, together with the internal capacity of the tube an oscillating circuit is formed, the wavelength of which is much smaller than the smallest wavelength of the main circuit.

1059. The Audion Oscillator. R. A. Heising. *Journal of the American Institute of Electrical Engineers*, 39, pp. 365—376, April, 1920, and pp. 471—478, May, 1920. *Electrical World*, 75, p. 1101, May 8th, 1920—Abstract. *Technical Review*, 6, pp. 506—507, June 8th, 1920—Abstract.)

The article covers the theory and operation of triode valve oscillator circuits. Vector diagrams are given of the phase relations in various circuits and the behaviour of the oscillator is considered as a function of its many variables, a series of curves being given in terms of the six independent variables of the circuit. The problem of securing high efficiency is also discussed. The scope of the paper may best be indicated by a list of the most important sections :—General oscillator circuits ; The simple oscillator circuit ; Simple vector diagrams ; Vector diagram including resistance ; Vector diagram with mutual inductance between grid

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and plate circuits; Phase relations in the Colpitts circuit; The ordinary feed-back circuit; Determination of frequency; Application to complex circuits; Coupled circuits; Feed-back circuits; Operation point on the characteristic curves; Dynamic characteristic of an audion with attached circuit; Coupling for power; Audion output impedance; Coupling adjustment; Audion load circuit; Oscillator behaviour as a function of its variables; Variation with filament current, with coupling, with input on grid, with antenna resistance and with grid resistance; Efficiency; Oscillator adjustments, and adjustments for multi-tube oscillators.

1060. THE FIRST WIRELESS TELEPHONE EXCHANGE. (*Telegraph and Telephone Age*, 38, p. 425, August 1st, 1920.)

A note referring to the installation of a special telephone exchange at Avalon, Catalina Island off the Californian coast for providing automatic relay connection between the subscribers' telephone stations at Catalina Island and the mainland.

1061. WIRELESS TELEPHONES. Société Française Radio-Électrique. (*French Patent* 502722, February 15th, 1916. Published May 25th, 1920.)

This specification describes a wireless telephone apparatus using a triode valve. For details, see British Patent 127008.

1062. WIRELESS TELEPHONY. W. H. Eccles. (*Nature*, 105, pp. 519—522, June 24th, 1920.)

The author first points out the recent advances that have been made in wireless telephony and then proceeds to summarise the leading methods of telephonic modulation of a C.W. source. In addition to direct modulation by a microphone in the aerial circuit, Fessenden's condenser microphones, Alexanderson's magnetic modulator and various forms of valve modulation are briefly described. At the end of the article two examples are quoted of high power plants, the first being the Western Electric Company's apparatus which was used for speaking across the Atlantic and from Arlington to Honolulu and the second the 20 kW set recently erected by Marconi's Wireless Telegraph Company. An outline connection scheme for the latter apparatus is included and shows that the modulation is effected by a number of absorption valves shunting the aerial circuit.

1063. DUPLEX WIRELESS TELEPHONY: SOME EXPERIMENTS ON ITS APPLICATION TO AIRCRAFT. P. P. Eckersley. (*Journal of the Institution of Electrical Engineers*, 58, pp. 555—565; Discussion, pp. 565—571, July, 1920. *Model Engineer*, 43, pp. 111—115, August 5th, 1920; also pp. 126—130, August 12th, 1920—Abstract.)

Paper read before the Institution of Electrical Engineers (for abstract see RADIO REVIEW, 1, pp. 338—340, 383—385, April and May, 1920 *), together with an appendix communicated after the reading of the paper and the discussion.

The additional appendix deals with the equations expressing the frequencies of the radiated waves with voice modulation superimposed upon the steady C.W. The possibility of eliminating the initial unmodulated C.W. frequency, or the carrier wave frequency, is also discussed, and it is pointed out that with a "quiescent aerial transmitter," of the type described in the paper, this may be effected by arranging matters so that the speech modulation is as much above as below the line of zero amplitude. A suggestion is also made as to the manner in which it might be possible to modify the circuits described in the paper to realise these conditions.

In the discussion some curves are given by C. L. Fortescue to explain the bad speed obtained with the quiescent aerial transmitter as compared with the ordinary modulated transmitter. In the former case unwanted harmonics may be introduced at the receiver by reason of the unsymmetrical waveform. The question of the lag in the establishment of the H.F. oscilla-

* See also RADIO REVIEW Abstract No. 623, August, 1920, for further references.

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tions was also dealt with by H. M. Dowsett and P. P. Eckersley, the former showing that the valves themselves could not account for a greater lag than about 10^{-5} sec. and that therefore the observed lags of 1/300 sec. must be attributed to the circuits themselves. H. J. Round's suggestion that the bad speech is due to the successive wave trains not being in phase in the quiescent aerial transmitters whereas in the cases where a feeble oscillation is permanently maintained they are in phase, appears to be the most promising.

1064. Receiving Aerials and Circuits. G. Leithauser. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 178—200, March, 1920.)

A study of the arrangements for allowing reception to be carried on while transmitting by means of a neighbouring aerial, as in duplex workings.

With a high degree of amplification one cannot use earthed aerials or even ordinary counterpoises because of the disturbing noises, one must employ open or closed directive systems. A horizontal insulated wire 200 metres long and 6 to 10 metres above the ground gives disturbing noises owing to rapid changes of air potential. Several methods of supporting large closed aerials on masts are discussed. The author then describes the heterodyne method of reception and the use of amplifiers. He discusses the relative advantages of large and small frame aerials. In a room where a large rotating coil is inconvenient, coils can be mounted flat on the four walls and connected to a radiogoniometer. He states that atmospheric disturbances are less with high narrow coils than with low wide coils.

1065. Experiments and Tests with Wireless High-speed Telegraphy. F. Banneitz. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 90—93, August, 1920.)

A description of a high-speed wireless system which has been developed in connection with the network of wireless stations now being established throughout Germany. The transmitter consists of thermionic tubes delivering 800 watts to the aerial which is not directly connected to the tubes but coupled to the oscillatory anode circuit. It is essential to secure the antenna very rigidly to prevent small changes of capacity due to the wind. In the grid circuit is a double-current relay operated by a Wheatstone high-speed transmitter. The receiving aerial is coupled through a number of amplifiers to the double-current rectifier, shown in Fig. 4.

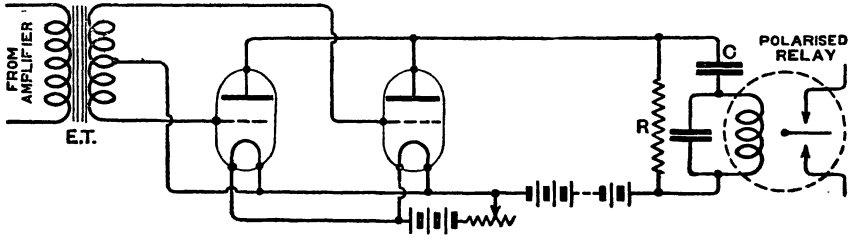

Fig. 4.

The grid battery is adjusted so that an E.M.F. in either direction in the transformer ET causes an increase in the anode current. The relay winding is only 50 ohms whereas the shunt R is 7,000 ohms, hence the receipt of a signal causes a rush through the relay winding to charge the condenser C; this throws the tongue over to marking; on the cessation of the signal, the condenser discharges and the tongue moves back to spacing. Other schemes are described in the article. Instead of an elevated aerial in some cases two closed frames at right angles are used connected to a goniometer. In the experiments between Berlin and Königsberg the transmitter was at Königswusterhausen, the receiver at Teltow, whilst the Wheatstone transmitter and inker were at the main telegraph office in Berlin, connection with which was obtained by superposition upon the telephone circuits. The speed obtained depended on the degree of interference, but reached a maximum of 300 letters a minute.

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1066. APPARATUS FOR ALTERATION OF WAVELENGTH. E. F. Huth and S. Loewe. (*German Patent* 307713, January 16th, 1916. Patent granted October 7th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 346, April, 1920.)

An arrangement in which a variable condenser and a variometer are controlled by means of a single handle.

1067. TUNING DEVICE FOR WIRELESS TELEGRAPHY. E. F. Huth. (*German Patent* 307714, November 25th, 1917. Patent granted October 7th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 346, April, 1920.)

A variometer for use in the transmission and reception of sustained waves consisting of a short-circuited coil coupled to the main circuit. Comparatively large alterations in the position of the short-circuited coil produce only small variations in the main self-inductance.

1068. NOTE ON THE INPUT IMPEDANCE OF VACUUM TUBES AT RADIO FREQUENCY. J. Weinberger. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 234—341, August, 1920.)

The high frequency input impedance of a triode valve (*i.e.*, impedance of the grid-to-filament path) for negative grid voltages is not infinite as the ordinary direct current characteristic would lead one to expect, but varies considerably with the frequency. Because of the considerable capacitative coupling between the grid-to-filament path and the plate-to-filament path the apparent input impedance is also found to be a function of the character of the output circuit. A substitution method of measuring the apparent input resistance for any particular tube is described. Using this method it was found with a Western Electric valve, Type D, that as the output resistance was varied from zero to 5 megohms the apparent input resistance varied from infinity down to a minimum of 50,000 ohms and then up to 170,000 ohms. An inductance inserted in the anode circuit produced a diminution of effective input impedance, while a capacitative output circuit produced neither a positive nor negative effect at the input terminals.

In the discussion L. M. Hull showed the deductions made from the experimental results to be considerably in error in that the input impedance is regarded as a pure resistance whereas Miller (see RADIO REVIEW Abstract No. 416, June, 1920) has shown that the input impedance of a tube having a pure resistance load in the anode circuit should be represented by a resistance in series with a capacity.

1069. EXPERIMENTS ON WIRELESS DIRECTION FINDING IN AIRCRAFT. R. Baldus and E. Buchwald. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 214—236, March, 1920. *Science Abstracts*, 23B, pp. 399—400, Abstract No. 766, August 31st, 1920—Abstract.)

Further details of tests made at the military aerodromes at Döberitz and Lärz.* Signals were sent out from the aeroplane and picked up on a Bellini-Tosi type of receiving antenna. Tests were also made with horizontal cross receiving antennæ, the results being very similar.

1070. RADIO DIRECTION CHANGES AND VARIATIONS OF AUDIBILITY. C. Kinsley and A. Sobey. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 299—325, August, 1920.)

Describes experimental work carried out with the aim of determining to what extent electromagnetic waves change their direction as measured by the radiogoniometer and to obtain the relation existing, if any, between changes of audibility and changes of direction. Using a radiogoniometer it has been found that the minima lie 90° from the direction of the transmitting station—using normal daylight conditions—even though the maximum vector does not lie along this direction, a typical example showing that where the angle between

* See RADIO REVIEW Abstract No. 672, August, 1920.

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true direction and maximum vector was 10° the direction indicated by the minima observations was only thirty-five minutes in error. The audibility meter used consisted of an iron core inductive resistance in series with a high resistance telephone, shunted by a non-inductive resistance, the audibilities being computed by using the impedance of the telephone, and not the resistance, in the usual equations. It was found that during sunlight the direction measurements varied but little though they were extremely erratic during the night. In the case of transmitters employing an undamped wave of great wavelength more directional distortion is found than when a transmitting system using damped waves and a shorter wavelength is employed.

The changes in audibility are of much more frequent occurrence and are proportionally much larger than the changes in direction, while there appears to be no evident relation between audibility and direction changes. There is much evidence to support the view that the audibility changes follow a diurnal cycle as well as a seasonal one. Various theories to account for the observed phenomena are proposed, notably that in which reflection at the atmospheric "isothermal layer" (10 km high) is assumed.

1071. MEASUREMENT OF THE ELECTROMAGNETIC FIELD OF WAVES RECEIVED DURING TRANS-OCEANIC RADIO TRANSMISSION. G. Vallauri. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 286—298, August, 1920.)

This article was first published in *L'Elettrotecnica*,* and its subject-matter has already been dealt with in the editorial article in the October issue of the RADIO REVIEW.† In the discussion of the paper as published by the Institute of Radio Engineers, Dr. Austin emphasises his belief that the Naval (Austin) formula would agree with the *average* current received at Leghorn from Annapolis with an error not much greater than 50 per cent. Fuller's formula is also stated to be probably in error on account of the assumption made in the experimental work that the received telephone current (in which a tikker was used) is proportional to the power in the antenna, whereas it is more nearly proportional to the received antenna current.

1072. ON THE PROPAGATION OF ELECTROMAGNETIC WAVES AROUND THE EARTH. B. van der Pol. (*Philosophical Magazine*, 40, p. 163, July, 1920.)

A short note pointing out an error in the earlier paper by the same author,‡ in connection with the comparison of the theoretical and observed received currents in radio transmission over long distances. This error reduces the discrepancy between the theoretical and observed values, but does not invalidate the author's previous conclusions.

1073. OBSERVATIONS ON RADIO TRANSMISSION PHENOMENA. (*Scientific American*, 123, p. 129, August 7th, 1920.)

Reference is made to an arrangement between the United States Bureau of Standards and the American Radio Relay League for the systematic observation of radio transmission phenomena as regards fading of signals and variation of signal strength with meteorological conditions.

1074. EXPERIMENTS ON THE FILTERING OUT OF THE HARMONICS FROM THE NAUEN SIGNALS. A. Meissner and K. W. Wagner. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 200—214, March, and pp. 392—406, May, 1920. *Technical Review*, 6, p. 690, August 17th, 1920—Abstract. *Science Abstracts*, 23B, pp. 395—397, Abstract No. 760, August 31st, 1920—Abstract.)

The oscillations produced in the aerial by an arc, a Goldschmidt alternator, or an alternator

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* See RADIO REVIEW Abstract No. 958, October, 1920, for references.

† RADIO REVIEW, 1, pp. 652—655, October, 1920.

‡ RADIO REVIEW Abstract No. 48, November, 1919.

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with frequency doublers, always contain higher harmonics which produce interference when receiving by the heterodyne method other continuous wave stations working at a smaller wavelength. At the suggestion of Max Wien the authors carried out tests to get rid of the harmonics in the Nauen aerial. These were caused mainly by the magnetic phenomena in the doublers, but were not of sufficient magnitude compared with the fundamental to be detected on a wavemeter. The success of the various devices was tested at three receiving stations, 4, 30, and 200 kms away. The harmonics were all those of the main aerial frequency up to the ninth and all the odd ones of the two foregoing frequency steps up to the seventh. With increasing excitation the harmonics increased more rapidly than the main wave. As the result of a number of trials the arrangement adopted consisted of a condenser and inductance in parallel across the secondary terminals of the last transformer which are connected also to the antenna and earth. This circuit tuned to the aerial frequency offers a high impedance to the main frequency but a low impedance to other frequencies. In addition to this two circuits consisting of inductance and capacity in series, tuned to the frequencies of the two principal harmonics were connected between the same terminals, thus giving additional paths of low impedance to these harmonics. The antenna current was only decreased 3 per cent., but the harmonics were almost entirely removed.

Experiments were also made on an artificial antenna in the laboratories of Siemens and Halske to test the efficacy of inserting a filter between the transformer and the antenna. This filter consisted of two elements of an artificial line. This proved very successful in removing the harmonics and had the advantage of being independent of tuning; it was thus unaffected by variations of generator speed.

1075. VALVE AMPLIFYING CIRCUIT FOR WIRELESS TELEGRAPHY. C. Lorenz. (*German Patent* 308411, December 18th, 1917. Patent granted October 10th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 165, February, 1920—Abstract.)

A retroactive circuit in which any number of tubes can function in parallel. The switches are so arranged that as the number of tubes in use increases the retroactive coupling becomes looser. See Fig. 5.

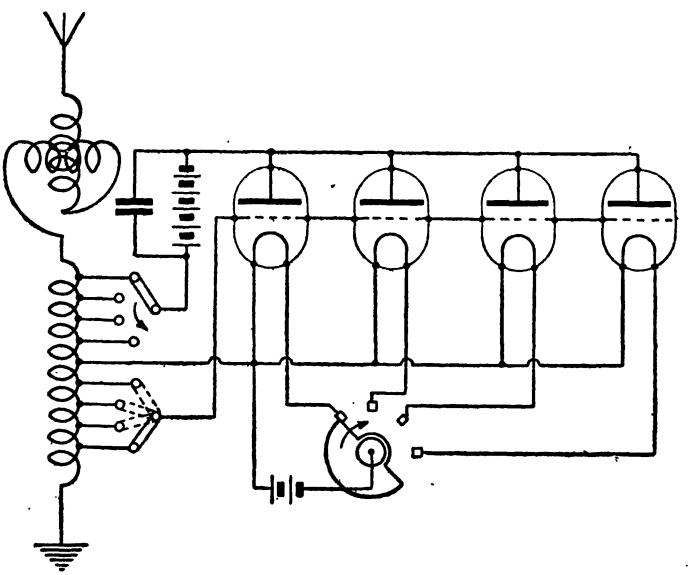

FIG. 5.

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1076. Receiving Circuit for Sustained Waves. Gesellschaft für drahtlose Telegraphie. (*German Patent* 308414, April 15th, 1914. Patent granted September 23rd, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 232, September, 1920.)

A circuit (see Fig. 6) in which an alternating current produced in the anode circuit of the

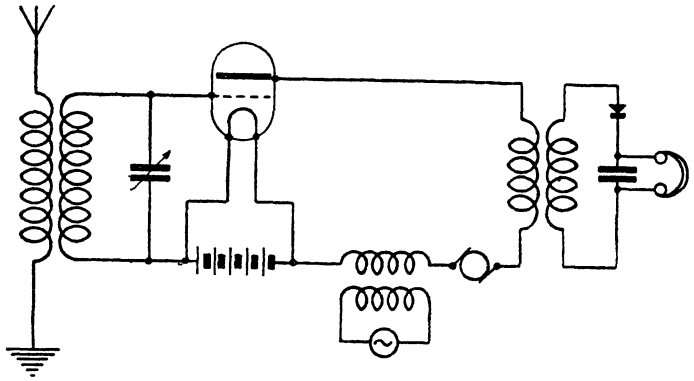

Fig. 6.

tube by an external heterodyne continues with the incoming oscillation to produce beats. Signals are received in an aperiodic detector circuit.

1077. Receiving Heterodyne Arrangement. Société Française Radio-

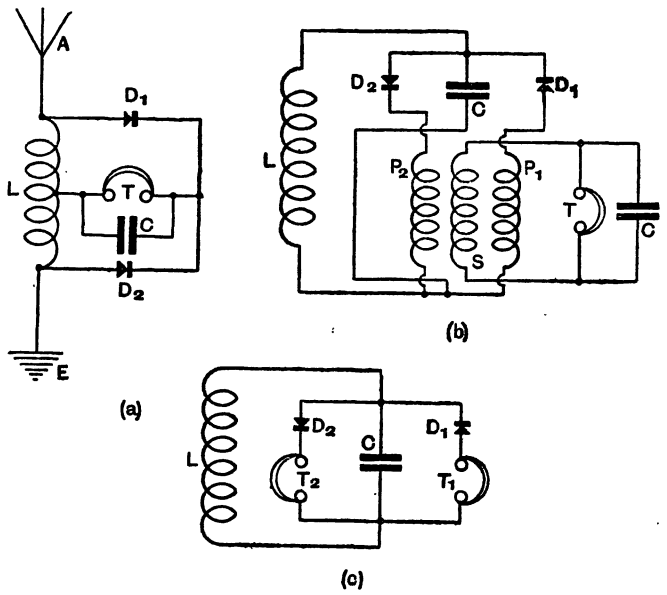

Fig. 7.

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Électrique. (*French Patent* 502041, February 11th, 1915. Published May 1st, 1920.)

The invention relates to means for increasing the sensitiveness of receiving apparatus by employing two rectifying detectors of different polarities as for example in the manner indicated in Fig. 7 (a) in combination with a heterodyne arrangement. The specification shows various ways of arranging the two detectors. In Fig. 7 (c), L is the secondary inductance of the receiving circuit. In parallel with the condenser C are connected two detectors D_1, D_2, each in series with a telephone T_1, T_2 respectively. By employing a transformer with windings P_1, P_2 and a single secondary, a single telephone can be employed as shown in Fig. 7 (b). By combining this method with a heterodyne arrangement permitting the introduction of an auxiliary radio-frequency voltage in the circuit, so that the fraction of the current rectified is proportional to the voltage applied to the detectors, it is claimed that a sensitiveness can be obtained which is twice that of the usual arrangements.

1078. RECEPTION OF UNDAMPED WAVES: CONSTRUCTION OF A HETERODYNE. F. Duroquier. (*La Nature*, 48(2), Supplement p. 43, August 7th, 1920.)

The arrangement described constitutes a single valve receiver arranged for autodyne reception of continuous waves with an alternative of a crystal detector for spark reception.

1079. RECEPTION OF UNDAMPED WAVES. F. Duroquier. (*La Nature*, 48(2), Supplement pp. 3—4, July 3rd, 1920 and Supplement p. 12, July 10th, 1920.)

Simple constructional details are discussed for a tikker receiver for C.W. reception.

1080. MACHINES FOR CONSTRUCTING THERMOPHONES. A. M. van Doorn. (*U.S. Patent* 1338886 and 1338887, March 1st, 1919. Patent granted May 4th, 1920.)

Describes machinery to facilitate the construction of thermophone receivers.

1081. HOW WIRELESS SIGNALS ARE RECEIVED. C. G. Crawley. (*Discovery*, 1, pp. 206—209, July, 1920.)

The author gives a popular summary of the development of radio receivers from the coherer to the modern three-electrode valve. Some of the applications of valves to wireless telegraphy and to high speed working are also referred to.

1082. RECEIVING CIRCUIT FOR WIRELESS TELEGRAPHY. Gesellschaft für drahtlose Telegraphie. (*German Patent* 310732, October 17th, 1918. Patent granted September 20th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 233, September, 1920.)

An adaptation of the so-called "fly wheel" circuit in which the heating battery of a triode and its circuital elements are used as the counterpoise for the antenna.

1083. SENDING AND RECEIVING CIRCUIT FOR WIRELESS TELEGRAPHY. E. F. Huth. (*German Patent* 310702, October 14th, 1917. Patent granted October 7th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 167—168, February, 1920—Abstract.)

A simple triode generating circuit which is transformed by means of a switch to a receiving circuit with a reduced anode voltage. Alteration of the coupling between the various circuits is thus avoided.

1084. RESONANCE WAVE COIL. G. O. Squier. (*Electrical World*, 76, p. 137, July 17th, 1920.)

Refers to the development of a resonance coil for radio reception which may be used either in conjunction with an ordinary aerial or as its own antenna. The coil has goniometric properties. See also RADIO REVIEW Abstract No. 854, September, 1920.

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1085. The Use of Electric Light Mains for the Reception of Wireless Signals. M. Thiercelin. (*La Nature*, 48(2), Supplement p. 22, July 17th, 1920.)

A short note describing apparatus used for the reception of wireless signals using electric light wires for aerial, a small condenser being interposed between the power circuit and the receiving apparatus.

1086. Aerials. R. O. Ranger. (*French Patent* 501746, July 18th, 1919. Published April 22nd, 1920.)

An arrangement of receiving antennæ is described in this specification such that the effects produced by a signal from a distant transmitting station are conveyed separately to a single receiving apparatus from a number of antennæ. The effects act collectively on this receiving apparatus independently of all relations between the wavelengths employed and the distances separating the aerials. In Fig. 8, T represents the transmitting station, and A_1, A_2,

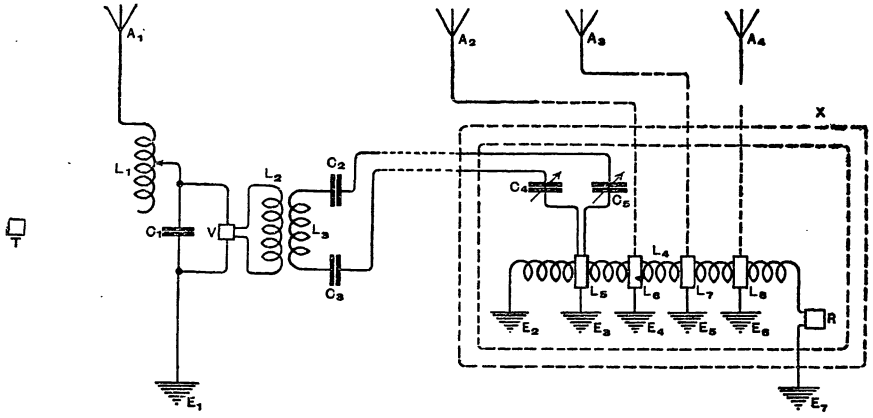

Fig. 8.

A_3, A_4 the separate receiving antennæ which may be separated at equal or other distances from one another and from the transmitting station. The antenna A_1 is connected to an inductance L_1 and thence to earth through the condenser C_1. The terminals of this condenser are joined to a high frequency amplifier designated by V, and thence to the primary winding of the transformer L_2, L_3. The secondary L_3 of this transformer is joined through the condensers C_2, C_3 to the receiving apparatus X. Two variable tuning condensers C_4, C_5 are also included in the circuit at the receiver. At the receiver, a coil L_4 is connected to earth through the receiving instrument R, and is provided with a number of movable coils L_5, L_6, L_7, L_8, connected to their respective aerials in the manner indicated in the case of L_5. The effects of the received signals from T are thus combined together and conveyed to R, the maximum effects being obtained by adjusting the positions of the sliding coils.

1087. Wireless Telephony in Holland. (*Telefunken Zeitung*, 4, No. 20, pp. 74—75, May, 1920.)

A short description of two small stations erected for the Dutch postal authorities; one is at the Hague and sends weather reports to lightships, the other at Soesterberg.

1088. Wireless Telegraphy in Finland. (*Electrical Review*, 86, p. 721 June 4th, 1920.)

Refers to the establishment of a network of wireless telegraph stations for press messages.

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1089. A LARGE SWEDISH RADIO STATION. (*La T.S.F. Moderne*, 1, p. 64, May, 1920.)

Reference is made to a project for the establishment of a station in Sweden near Falkenberg for communication with the United States. The aerial is to be supported by towers 650 feet high. The wavelength is to be 17,000 metres and the station is to employ from 300 to 400 kW. It is hoped that it will be ready for operation in 1923.

1090. WIRELESS IN MESOPOTAMIA AND PERSIA. W. Wettlanger. (*Telefunken Zeitung*, 4, No. 20, pp. 43—56, May, 1920.)

Some details and illustrations are given of the portable, and other stations, and of the ranges worked.

1091. CARNARVON RADIO STATION. (*Electrical Experimenter*, 7, pp. 778 and 826—827, December, 1919.)

An illustrated description abstracted from the *Wireless World*, 7, pp. 301—307, September, 1919.

1092. TROPICAL RADIOTELEGRAPH COMPANY'S STATIONS AND EQUIPMENT. (*Telegraph and Telephone Age*, 38, pp. 272—275, May 16th, 1920.)

A short illustrated description of the New Orleans and Swan Islands Stations and of some ship installations fitted by the Tropical Radiotelegraph Company.

1093. LONG DISTANCE RADIO COMMUNICATION IN CHILI. E. W. Fielding. (*Technical Review*, 6, p. 507, June 8th, 1920—Abstract.)

See also RADIO REVIEW Abstract No. 451, June, 1920.

1094. REMINISCENCES OF WIRELESS ON THE BLIMP PATROL. M. B. Egan. (*Wireless World*, 7, pp. 557—563, January, 1920.)

Some of the wireless apparatus used on anti-submarine patrol aircraft is described and illustrated.

1095. AN EXPERIMENTAL STATION. E. Ludwig. (*Wireless World*, 7, pp. 583—586, January, 1920.)

Constructional details are given.

1096. RADIO FOG SIGNALLING. (*Electrical Experimenter*, 7, p. 909, January, 1920.)

Some experiments carried out by the Bureau of Standards, Washington, and by the Bureau of Lighthouses, U.S.A., are referred to, relative to the use of radio signals from lighthouses in Chesapeake Bay. A rotating frame aerial and four-stage amplifier was used on the ship and it was found that at a distance of fifty miles the position of the ship could be determined to less than half-a-mile.

1097. THE NEW MEXICAN TELEFUNKEN STATION AT CHAPULTEPEC. (*Telefunken Zeitung*, 41, No. 20, pp. 19—22, May, 1920.)

An illustrated description of the station which has a 150—170 kW 500-cycle alternator, a 100,000 volt transformer and a quenched spark gap.

1098. TELEFUNKEN EXHIBITION. (*Telefunken Zeitung*, 2, No. 18, pp. 11—28, October, 1919.)

Description of an exhibition of Telefunken apparatus old and new, which has since been put on a permanent basis at the headquarters of the company in Berlin.

1099. THE ARCHITECTURE OF THE NAUEN STATION. H. Mathesius. (*Telefunken Zeitung*, 3, No. 17, pp. 33—45, August, 1919.)

A well-illustrated descriptive article.

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1100. Duplex Receiving Apparatus at Geltow. A. Esau. (*Telefunken Zeitung*, 17, pp. 75—78, August, 1919.)
A brief description of the station near Potsdam, which serves as the receiving station in the Nauen duplex system.

1101. Mica Condensers for Radio Sets. (*Electrical Experimenter*, 7, p. 781, December, 1919.)
Two patterns of enclosed radio transmitting condensers with mica dielectric are illustrated.

1102. The Design and Construction of Condensers for Radiotelegraphy. P. Maurer. (*L'Électricien*, 51, pp. 278—279, July 1st, 1920.)
The author deals with the difficulty of constructing small receiving condensers to any given capacity, and refers to the advantages of series-parallel connection of small condenser units to obtain the desired capacity values.

1103. Electric Condensers. W. Dubilier. (*British Patent* 141658, July 24th, 1919. Convention date, April 11th, 1919. Patent not yet accepted but open to inspection. *Wireless Age*, 7, pp. 19—20, June, 1920—Abstract.)
The construction of multi-plate condensers is described, in which the plates are formed of some hard material such as copper coated on both sides with a soft material such as lead foil which may be pressed into intimate contact with the irregularities of the dielectric sheets. The copper "core" to the plates enables greater conductivity to be obtained in the plates.

1104. Electric Condensers. W. Dubilier. (*British Patent* 141690, April 1st, 1920. Convention date, April 11th, 1919. Patent not yet accepted but open to inspection. *Wireless Age*, 7, pp. 22—23, March, 1920—Abstract.)
The construction of condensers having a number of units in series is described, the terminal connections between the succeeding sections being arranged at various points round the block of sections so that the use of insulating barriers between them is avoided.

1105. Electric Condenser. E. A. Bayles. (*British Patent* 139694, May 23rd, 1919. Patent accepted March 11th, 1920.)
The arrangement of a battery of oil-immersed condensers in a containing tank is dealt with.

1106. An Efficient Variable Condenser. G. W. Hale. (*Wireless World*, 7, pp. 630—632, February, 1920.)
Constructional details and dimensioned drawings are given.

1107. Condensers and Resistances. (*La T.S.F. Moderne*, 1, pp. 56—58, May, 1920.)
Constructional details are given of simple forms of grid and intervalve coupling condensers and of grid and anode resistances for valve circuits.

1108. A Wet Cotton Grid Leak and Intervalve Resistance. E. W. Kitchin. (*Wireless World*, 8, pp. 265—266, July 10th, 1920.)
This article deals with some experiments on the use of a wet cotton thread for grid leaks and intervalve resistances for amplifiers. For a grid leak the cotton thread is attached to two copper wire terminals which are hermetically sealed into a rubber tube filled with distilled water; while for anode circuit resistances a loop of cotton may be suspended in a small hermetically sealed receptacle containing distilled water to maintain the cotton in a wet condition.

1109. A New Type of High Resistance. F. Skaupy and H. Ewest. (*Zeitschrift für technische Physik*, 1, pp. 167—169, August, 1920.)
Graphite is deposited on spirals of insulating material, generally glass, which are then

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preferably enclosed in a glass bulb filled with hydrogen because of its superior heat conduction. The bulb is fitted with an Edison socket like a glow lamp or fitted with a metal clip at each end for convenient insertion in a socket. The results of tests on three resistances of $3{\cdot}6.10^3$, 14.10^3 and 33.10^3 ohms respectively, showed that with currents of 5, 4 and 2 milliamperes the resistances immediately took up their final value, whereas with currents of 42, 21 and 9 milliamperes an interval of from 7 to 15 minutes elapsed before the steady values were attained, the resistances falling from 3 to 9 per cent. of their initial value. On cutting off the current they regain their initial value. When tested with very small currents they showed no signs of troublesome contact resistance.

They can stand a continuous load of 1 watt per square centimetre of graphite surface. They are being made in standard sizes for values ranging between 1,000 and 500,000 ohms.

1110. TELEGRAPHING BY INVISIBLE LIGHT BEAMS. H. Gernsbach and H. W. Secor. (*Electrical Experimenter*, 7, p. 1126, March, 1920.)

Some editorial notes referring to the article by H. de Gallaix on telegraphy with infra-red rays (see Abstract No. 1019, October, 1920). It is mentioned that successful transmission has been obtained by this means between Sandy Hook and the Woolworth Building in New York City, the distance being eighteen miles.

1111. TALKING OVER A SUNBEAM. A. O. Rankine. (*Electrical Experimenter*, 7, pp. 1263 and 1315—1316, April, 1920.)

A summary of some of the methods of photophony, and of the author's arrangements.*

1112. SIGNALLING BY INVISIBLE RAYS. (*Engineering*, 109, pp. 797—798, June 11th, 1920.)

A brief *résumé* of maritime development in signalling by ultra-violet and infra-red rays. The researches of Case, Coblentz and Professor Wood are briefly summarised.

1113. THERMO-ELECTRICITY AND SOME OF ITS APPLICATIONS. P. R. Coursey. (*Wireless World*, 8, pp. 181—183, June 12th, 1920.)

The use of thermopiles for telephony by light and heat rays is referred to in this article.

1114. SUBMARINE SOUND RECEIVERS AND TRANSMITTERS. M. I. Pupin. (*British Patents* 139496 and 139497, February 25th, 1920. Convention date, February 4th, 1919. Patent not yet accepted but open to inspection.)

Apparatus is described for submarine sound signalling using high frequency impulses (of the order of 100,000 ~) using a condenser transmitter and a crystal receiver operated by changes of pressure (Piezo-electric effect).

1115. MODERN MARINE PROBLEMS IN WAR AND PEACE. C. V. Drysdale. (*Journal of the Institution of Electrical Engineers*, 58, pp. 572—597, July, 1920. *Engineering*, 110, pp. 484—486, October 8th, pp. 521—523, October 15th, and pp. 552—554, October 22nd, 1920—Abstract.)

Report of the Eleventh Kelvin Lecture delivered before the Institution of Electrical Engineers on April 15th, 1920. The paper deals with the wartime research work carried out by the Admiralty departments and is divided into four sections dealing respectively with Submarine Detection, Defence and Destruction, Navigational Applications, and General Scientific Research. The various types of hydrophones are fully described and also the "leader" cable and other aids to navigation. Appendices deal with the Theory of Acoustic Transmission; the Theory of Three-station Sound Ranging; Theory of the Propagation of Electromagnetic Waves in a Conducting Isotropic Medium (such as sea water); the Transmission of Alternating Currents through Large Conductors, and the Current and Field Distribution in a Conducting Medium surrounding a Cable carrying an Alternating Current.

* See RADIO REVIEW Abstracts No. 178, January, 1920, No. 255, March, 1920, and No. 731, August, 1920.

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1116. The Theory of Receivers for Sound in Water. H. A. Wilson. (*Physical Review*, 15, pp. 178—205, March, 1920. *Science Abstracts*, 23A, p. 397, Abstract No. 1000, July 31st, 1920.)

A mathematical paper divided into five sections dealing respectively with: (1) Single receivers; (2) two receivers as used for direction finding; (3) multiple receivers; (4) lines of receivers; (5) receivers distributed over large areas.

1117. Swivelling Brackets for mounting Electric Generators on Aircraft. F. J. Hooper. (*British Patent* 138212, March 24th, 1919. Patent accepted February 5th, 1920.)

Wind driven dynamos are mounted on aircraft by means of a swivelling bracket so that they may be brought to different angles with respect to the air stream in order to regulate their speed.

1118. Aircraft Radio. (*La Nature*, 48, pp. 156—165, April 10th, 1920. *Technical Review*, 6, p. 549, June 22nd, 1920—Abstract.)

A general article describing in detail the state of knowledge with regard to aircraft radio apparatus prior to the war and of the development of the various branches of radio work in aircraft during the war. Illustrations are given of some of the apparatus used both for telegraphy and telephony, while the installations used for direction finding are also dealt with.

1119. Man, Air and Ether—The First London-Paris Flight on a Handley-Page Commercial Machine fitted with Wireless Telephony. H. C. van der Velde. (*Wireless World*, 8, pp. 119—124, May 15th, 1920. *Technical Review*, 6, p. 589, July 6th, 1920—Abstract.)

An account of the trip from London to Paris and back on March 4th, 1920, of a Handley-Page machine carrying a wireless telephone installation. Some particulars as to the ranges obtained are given throughout the article, which is also accompanied by a photographic illustration of the gear.

1120. Aircraft Wireless Sets: The 54A Spark Transmitter. J. J. Honan. (*Wireless World*, 7, pp. 512—514, December, 1919.)

An illustrated description.*

1121. How Aeroplanes are Navigated by Wireless. R. Keen. (*Wireless World*, 7, pp. 578—582, January, 1920.)

This paper summarises the difficulty of D.F. work on aircraft.†

1122. Wireless Service on Aircraft Routes. (*Wireless World*, 8, pp. 237—240, June 26th, 1920. *Technical Review*, 6, pp. 724—725, August 31st, 1920.)

The various applications of wireless telephony in aircraft are discussed.

1123. The Elimination of Magneto Disturbance in the Reception of Wireless Signals on Aircraft. J. Robinson. (*Science Abstracts*, 23B, pp. 165—166, Abstract No. 334, March, 1920—Abstract.)

See Radio Review, 1, pp. 105—110, December, 1919, for original paper.

1124. "The Elimination of Magneto Disturbance." L. J. Voss. (*Radio Review*, 1, pp. 258—259, February, 1920.)

Correspondence relative to the paper by J. Robinson with the above title.‡

1125. Hello, Mars. H. W. Secor. (*Electrical Experimenter*, 7, p. 48, April, 1920.)

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* See also Radio Review Abstract No. 258, March, 1920.

† See also Radio Review Abstract No. 361, May, 1920.

‡ Radio Review, 1, pp. 105—110, December, 1919.

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1126. INSULATING MATERIALS. (*Telegraph and Telephone Age*, 38, pp. 73—74, February 1st, 1920.)
A *resumé* of the chief properties of electrose, fibre, and the bakelite products as insulating materials, and also in connection with their use in radio work.

1127. EARLY EXPERIENCES OF A WIRELESS AMATEUR. W. J. Fry. (*Wireless World*, 7, pp. 602—604, January, 1920.)
Some early experiments with coherers and similar apparatus are described.

1128. TRAINING OF AN R.A.F. WIRELESS OPERATOR. M. B. Egan. (*Wireless World*, 7, pp. 621—627, February, 1920.)
The equipment of Flowerdown Training Camp, Winchester, is discussed and illustrated.

1129. M. BRANLY'S DONATION TO THE "POSTES ET TÉLÉGRAPHES" MUSEUM. (*Annales des Postes, Télégraphes et Téléphones*, 8, pp. 651—653, December, 1919. *Revue Générale de l'Électricité*, 7, p. 240, February 14th, 1920—Abstract.)
The early forms of Branly's coherers included in this donation are briefly described and illustrated.

1130. NAVAL OBSERVATORY TIME SIGNALS. (*Scientific American*, 122, p. 417, April 17th, 1920.)
Some of the results of observations on the accuracy of wireless time signals are quoted. The majority of the errors centred round 0·01 second. Figures for the transmission lags of some American stations are also given.

1131. NAUEN AFTER THE WAR. (*Telefunken Zeitung*, 4, No. 20, pp. 12—14, May, 1920.)
Deals with the radio traffic between Germany and U.S.A.

1132. WIRELESS TELEGRAPHY IN NORTH AMERICA. (*Elektrotechnische Zeitschrift*, 41, p. 416, May 27th, 1920.)
Refers to the signalling ranges of some of the high power American stations.

1133. ELECTRICAL ENGINEERING—WIRELESS. (*The Times Engineering Supplement*, No. 543, p. 29, January, 1920.)
Very brief notes *re* wireless progress during 1919.

1134. MAGNETIC STORMS AS AFFECTING OCEAN TELEGRAPH CABLES. E. Raymond-Barker. (*Electrical Review*, 86, p. 293, March 5th, 1920.)
Refers to the application of wireless to giving warnings of magnetic storms.

1135. TIME TABLE OF THE PRINCIPAL RADIOTELEGRAPHIC TRANSMISSIONS. F. Duroquier. (*La Nature*, 48, Supplement p. 9, January 10th, 1920. *Revue Générale de l'Électricité*, 7, p. 54B, February 21st, 1920.)
The table includes particulars as to the messages sent (press, time-signals, etc.) and states the wavelength and whether damped or continuous waves.

1136. WIRELESS TELEGRAPHY AND THE UNIFICATION OF TIME. (*L'Électricité*, 2, p. 1, February 15th, 1920.)
Suggests the utility of wireless signals for securing agreement in clock readings at railway stations.

1137. WIRELESS IN WARFARE. (*Telegraph and Telephone Journal*, 6, pp. 164—166, July, 1920.)
Describes the methods of wireless signalling from aircraft used for directing artillery fire.

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1138. Inter-imperial Communication through Cable, Wireless and Air. C. Bright. (*Génie Civil*, 76, p. 284, March 13th, 1920; *Revue Générale de l'Électricité*, 7, p. 196D, June 19th, 1920—Abstract.)
See Radio Review Abstract No. 204, February, 1920, for reference to the original paper.

1139. Sensitive Apparatus for the Measurement of Alternating Currents. H. Abraham, E. Bloch and L. Bloch. (*Zeitschrift für Instrumentenkunde*, 40, p. 79, April, 1920—Abstract.)
See Radio Review Abstract No. 5, October, 1919.

1140. Old and Modern Telephones. W. J. Fry. (*Wireless World*, 8, p. 167, May 29th, 1920.)
Some historic telephone receivers are illustrated in this short note.

1141. "Text-book on Wireless Telegraphy." Rupert Stanley; R. Whiddington. (*Radio Review*, 1, pp. 418—420, May, 1920.)
Correspondence relative to the above book by R. Stanley.*

1142. Speaking on a Battleship to a Crowd in New York City. (*Scientific American*, 122, p. 601, May 29th, 1920.)
Describes a recent experiment in which speech by Mr. Daniels from the *Pennsylvania* was rendered audible to a crowd in New York City. The constructional arrangement of the loud speaking telephone that was used is also given.

1143. The Use of a Valve Amplifier and Telephone for the Detection of α and β Particles from Radioactive Bodies. M. Holweck. (*Revue Générale de l'Électricité*, 7, p. 713, May 29th, 1920.)
Abstract of paper read before the Société Française de Physique.

1144. Wireless Telegraphy in the Red Sea during the War. G. Montefinale. (*Wireless World*, 7, pp. 679—683, March, 1920.)

1145. The Danger of Hertzian Waves. (*La Nature*, 48, pp. 252—253, May 15th, 1920.)
Briefly describes some experiments to test the possibility or otherwise of combustion being produced by sparks set up by Hertzian waves.

1146. High Frequency Multiplex Telephony and Telegraphy. H. Fassbender and E. Habann. (*Science Abstracts*, 23B, pp. 106—107, Abstract No. 201, February, 1920—Abstract. *Electrical World*, 76, p. 86, July 10th, 1920—Abstract.)
See Radio Review Abstract No. 322, April, 1920.

1147. Georg Graf von Arco. (*Telefunken Zeitung*, 3, No. 17, pp. 5—19, August, 1919.)
A biographical notice of Count von Arco, who with Slaby founded what afterwards developed into the Telefunken Company.

1148. Æther. P. R. Coursey. (*Wireless World*, 8, pp. 37—40, April 17th, 1920. *Technical Review*, 6, p. 467, May 25th, 1920—Abstract.)
A summary of some of the early theories of the æther and of some of the known facts relative to its properties. An "æther spectrum" is included covering the range of frequencies from 10 to 10^{20} per second with the positions of various known waves marked on the scale. A brief reference is also made to some of Sir J. J. Thompson's recently expressed views on the relation between æther and matter and on the mechanism of radiation.

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* See review in Radio Review, 1, pp. 252—253, February, 1920.

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1149. WIRELESS TELEGRAPHY. (*Nature*, 105, p. 17, March 4th, 1920.)
A brief note *re* wartime advances.

1150. HIGH FREQUENCY ELECTRIC SIGNALLING. L. N. Brillouin. (*British Patent* 138610, January 31st, 1920. Convention date, January 31st, 1919. Patent not yet accepted but open to inspection.)
Arrangements are described for signalling along wires using high frequency oscillations, with the oscillation source placed approximately at the centre of the line wires.

1151. ASTRONOMICAL ARRANGEMENTS BY WIRELESS TELEGRAPHY. Kobold. (*Nature*, 105, p. 403, May 27th, 1920.)
Arrangements are referred to for the distribution of astronomical information from the Nauen Station.

1152. THE LIFE AND WORK OF LORD KELVIN. E. Picard. (*Revue Scientifique*, 58, pp. 193—207, April 10th, 1920.)
A long summary of Lord Kelvin's scientific work and some of the theories proposed by him dealing with the ether, etc.

1153. A DIRECT CURRENT TRANSMITTER. L. M. Cockaday. (*Electrical Experimenter*, 7, p. 1282, April, 1920.)
Describes a transmitter using a rotary gap and a synchronous contact maker for producing the oscillations.*

1154. INTERPLANETARY WIRELESS. P. R. Coursey. (*Wireless World*, 8, pp. 1—7, April 3rd, 1920. *Technical Review*, 6, p. 467, May 25th, 1920—Abstract. *L'Elettrotecnica*, 7, p. 209, April 25th, 1920—Abstract.)
A critical discussion of the so-called messages from Mars, etc., and of the possibilities of wireless signalling between planets.

1155. RESEARCH FOR THE WIRELESS AMATEUR. W. T. Ditcham. (*Wireless World*, 8, pp. 113—116, May 15th, 1920.)
The author passes in review some of the lines upon which radio research may usefully be carried out. These include especially improvements in valves, C.W. receivers, X-stoppers, radiotelephone apparatus and auxiliary instruments generally.

1156. MAGNETIC STORMS. L. Pyle. (*Electrical Experimenter*, 7, pp. 876 and 920 and 922—924, January, 1920.)
The effect of sun spots and meteorological conditions upon the magnetic state of the earth is discussed and a number of magnetograph records are given.

1157. THE ROMANCE OF INVENTION. XIII. GENERAL G. O. SQUIER. C. H. Claudy. (*Scientific American*, 122, p. 620, June 25th, 1920.)
A brief *resumé* is given of General Squier's work on wired wireless and of his development of Signal Corps radio work.

1158. AN ANEMOMETER EMPLOYING ELECTRIC OSCILLATIONS. E. Rothe. (*Comptes Rendus*, 170, pp. 1197—1198, May 17th, 1920.)
The application of a small radio transmitter to an anemometer mounted in a small captive balloon or kite is described, so that its indications may be electrically transmitted to the ground using only a single conductor which serves as the mooring wire for the balloon. The indications are received on ordinary radio-receiving apparatus located on the ground, and connected or coupled to the mooring wire.

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* See also RADIO REVIEW Abstract No. 111, January, 1920, for a further reference to this arrangement.

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1159. Multiplex Telegraphy and Telephony by High Frequency Currents on Wires. (*Telefunken Zeitung*, 4, No. 20, pp. 5—7, May, 1920.) Also High-Frequency Telephone Exchange. P. Schwarzhaupt. (*Telefunken Zeitung*, 4, No. 20, pp. 7—11, May, 1920.)

In Germany high frequency telephony over wires has been in use for some months over an experimental line. The methods are those of wireless telephony, both for transmission and reception.

1160. The Telephonic and Radiotelegraphic Administration in Germany. (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 31—36, March, 1920. *Technical Review*, 6, p. 506, June 8th, 1920—Abstract.)

A report of the Mission du Service d'Études et de Récherches Techniques issued February, 1920, and discussing the condition of the telephone system, etc., in Germany. Reference is made to the use of wired-wireless methods of communication between Berlin and Hanover and between Berlin and Frankfort. It is stated that the speech is better over the high frequency circuit than over the ordi y apparatus. As regards radiotelegraphy low power valve sets are being developed a the tendency is to replace all spark stations by C.W. apparatus.

1161. Wireless Transmission of Power. T. W. Benson. (*Electrical Experimenter*, 7, pp. 1118—1119, March, 1920.)

A suggestion for the transmission of high-frequency energy from place to place utilising the upper ionised layers of the atmosphere and ionised searchlight beams to make connection to them. *

1162. New Technical Department of the German Telegraph Administration. (*Elektrotechnische Zeitschrift*, 41, p. 677, August 26th, 1920.)

On account of the continual growth of the wireless system and of the use of high frequency telegraphy and telephony along wires in the Imperial Telegraph Department, special courses of instruction have been instituted for those higher and middle grade employees who are considered suitable for this new branch. In future all new entries to these grades will be instructed in wireless telegraphy in the same way as they are at present instructed in the other branches of telegraphy and telephony.

1163. Wireless Safety Device for Moving Trains. (*Elektrotechnische Zeitschrift*, 41, p. 573, July 22nd, 1920.)

A wireless device has been devised and tested by the Telefunken Co. for drawing the attention of the engine driver to any signal set at danger. The locomotive carries a valve transmitter, the oscillations of which prevent the operation of a lamp and buzzer. If the signal is set against the train, a loop on the permanent way is closed; this abstracts so much energy from the oscillatory circuit that the lamp and buzzer are set in operation. Very few details are given in this note.

1164. Merchant Shipping Wireless Telegraphy Rules. (*Electrician*, 85, p. 819, August 13th, 1920. *Electrical Review*, 87, p. 178, August 6th, 1920.)

Extracts are given from the new rules issued by the Board of Trade † and to come into force on September 3rd, relating to the installation of wireless apparatus on merchant vessels and of the auxiliary apparatus required in conjunction with it. Clauses are also included relative to the use of automatic apparatus for indicating incoming distress calls.

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* See Radio Review Abstracts Nos. 701 and 702, August, 1920.

† Statutory Rules and Orders, No. 976, 1920 (London: *H.M. Stationery Office*, pp. 5. Price 3*d.* net).

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1165. EIFFEL TOWER WIRELESS TIME SIGNALS. R. A. Samson. (*Nature*, 105, p. 268, April 29th, 1920.)

Particulars are given of the revised programme for the transmission of "scientific" time signals from the Eiffel Tower. Additional sets of signals are now being sent at 10.30 a.m. (G.M.T.) and 11 p.m. (G.M.T.). These additional signals are sent with a musical note. The reference numbers referring to them are designated ML and are sent after the 11.45 signals together with the reference numbers for the 11.30 series, the latter being designated by the letters RF.

1166. THE METEOROLOGICAL BULLETIN OF THE BRITISH AIR MINISTRY. (*La T.S.F. Moderne*, 1, pp. 47—50, May, 1920.)

Particulars are given of the times of transmission, the wavelength and the codes used for these messages. Brief reference is also made to the two undamped wave transmitters installed at the Air Ministry Station in London, one of which has a range of 100 km and the other one of 2,400 km.

1167. THE EIFFEL TOWER TIME SIGNALS. (*Wireless World*, 8, p. 138, May 15th, 1920.)

Two charts are given of the time signals sent on the old and new systems.

1168. EIFFEL TOWER WEATHER REPORTS. (*Wireless World*, 8, pp. 175—176, May 29th, 1920.)

Particulars are given of the codes used for the meteorological reports transmitted from the Eiffel Tower three times daily.

1169. TIME SIGNALLING STATIONS. (*Wireless World*, 8, pp. 273—274, July 10th, 1920.)

A list of stations transmitting time signals in the various countries of the world, giving call letters, wavelengths, and times of transmission.

1170. WEATHER BULLETINS. (*Admiralty Notice to Mariners*, No. 703, 1920. *Wireless World*, 8, pp. 278—279, July 10th, 1920.)

A list is given of stations in the various countries of the world transmitting meteorological messages. The call letters, wavelengths, and times of transmission are given.

1171. METEOROLOGICAL SIGNALS OF THE EIFFEL TOWER. (*La T.S.F. Moderne*, 1, pp. 18—24, April, 1920.)

The signalling code used for the meteorological information sent out daily from the Eiffel Tower is set out in detail.

1172. WEATHER CHARTS BY WIRELESS. (*Flight*, 12, pp. 970 and 977, September 9th, 1920.)

Particulars are given of the revised scheme of meteorological reports issued by radiotelegraphy from the Air Ministry and from Aberdeen wireless stations. A list is given of the places from which reports are obtained and the code used for the signalling is also indicated.

1173. A METHOD OF AMPLIFYING ELECTRICAL VARIATIONS OF LOW FREQUENCY. W. H. Eccles and F. W. Jordan. (*Electrician*, 85, p. 176, August 13th, 1920.)

In order to extend the range of frequencies over which a given triode amplifier may be operated, the authors propose to amplify low frequency alternating currents (such for example as speech currents) by impressing them upon a high frequency carrier oscillation, which may be subsequently amplified by means of any ordinary form of radio frequency amplifier. One proposed arrangement of circuit is indicated in Fig. 9, which shows a three-electrode valve V, with the low frequency currents to be amplified impressed upon its anode circuit at T_1. The valve is arranged to generate the carrier frequency oscillations by means of the tuned circuit L C, and the reaction M on to the grid circuit. The modulated radio frequency currents may be taken off from the terminals A_1 and A_2 and thence led to the terminals of the amplifier arranged for high frequency amplification. Several other arrangements are possible by using the valve shown merely as a modulating valve, and impressing upon it both the high

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and the low frequency currents. The chief advantage of the method lies in the possibilities of increasing the amplification by means of resonance while avoiding distortion of the low frequency currents. It is claimed also that valve noises are reduced as compared with an ordinary low frequency amplifying arrangement.

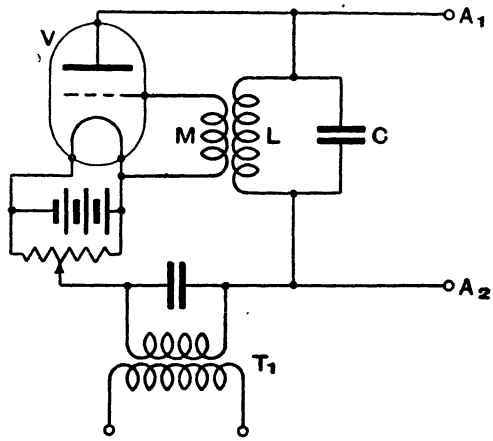

Fig. 9.

1174. Multi-stage Valve Amplifiers. M. I. Pupin. (*British Patent* 139494, February 25th, 1920. Convention date, February 4th, 1918. Patent not yet accepted but open to inspection.)

The essential feature of the arrangement described in this specification is the use of a filtering circuit between successive groups of amplifying valves. Referring to Fig. 10, V_1 V_2 V_3 and V_4 are four amplifying valves coupled together with the usual arrangement of resistance capacity couplings R_1 C_1, R_2 C_2, R_3 C_3, R_4 C_4. Of these the first three valves are preferably of high internal resistance while V_4 is of low internal resistance. The resistance R_4 should be of less value than R_1 R_2 R_3 and be approximately equal to the internal resistance of V_4. The filtering circuit proper consists of condensers C_5 C_6 C_7 C_8 and leak resistances R_5 R_6 R_7 R_8 which are all joined to earth at E_2. The point G should be joined to the input grid of a second

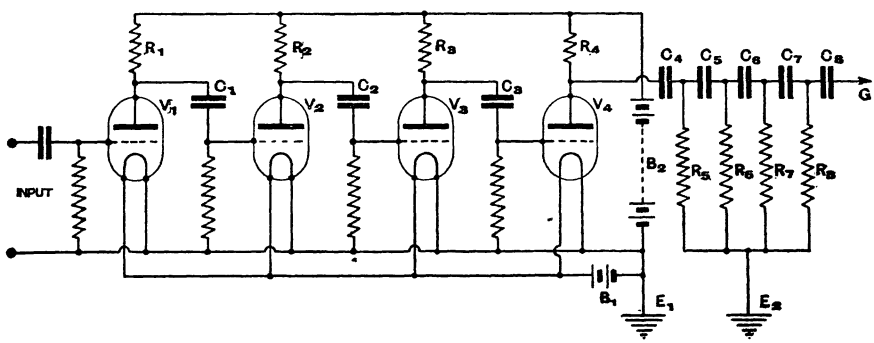

Fig. 10.

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group of valve amplifiers of exactly similar nature to V_1 V_2 V_3 V_4. Any number of groups of valves may be connected together by such an arrangement. If low resistance valves are used throughout, the condensers C_4 C_5 C_6 C_7 C_8 may with advantage be replaced by resistances, and resistances R_5 R_6 R_7 R_8 replaced by inductances. The actual filtering circuit is such as to destroy the reaction between the groups of amplifiers as regards internal and external disturbances but yet to allow the passage of the desired wave signals.

1175. THERMIONIC VALVE AMPLIFIERS. G. F. Partridge and B. S. Smith. (*British Patent* 137876, November 13th, 1918. Patent accepted January 29th, 1920.)

To a usual arrangement of resistance capacity coupled multi-stage valve amplifiers a special addition is made to prevent howling when more than three valves are employed. This modification is introduced in the grid of the third valve if the amplifier contains more than four or five stages, or in the grid of the fourth valve if the amplifier has six stages. The modification consists of a variable condenser placed in parallel with the grid leak of the valve in question, the resistance of this leak being much less than in the case of the other valves. The arrangement is described as being especially of use with low frequency amplifiers.

1176. VALVE AMPLIFIERS AND MEDICAL SCIENCE. J. Scott-Taggart. (*Electrician*, 85, p. 62, July 9th, 1920.)

The writer refers to some experiments in connection with the use of triode amplifiers in connection with microphonic stethoscopes for medical work. It is suggested that this provides a field for further research.

1177. THE USE OF AMPLIFIERS FOR LOCATING FAULTS IN ARMOURED CABLES. G. Rosche. (*L'Électricien*, 51, pp. 277—278, July 1st, 1920.)

Describes the use of three-electrode valve amplifiers used in conjunction with movable earth connections for locating leakage currents from cables.

1178. THE MAGNAVOX. (*Science and Invention*, 8, p. 408, August, 1920.)

A description of the Magnavox Loud Speaking Telephone comparing it with an ordinary type of receiver. A sectional diagram is given of the construction of the apparatus in which the diaphragm is actuated by a coil moving in a magnetic field and not by a direct pull from a fixed magnet as in an ordinary telephone receiver.

1179. HIGH FREQUENCY MULTIPLEX TELEPHONY AND TELEGRAPHY ALONG WIRES (Part II.).* H. Fassbender and E. Habann. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 407—423, May, 1920. *Science Abstracts*, 23B, Abstract No. 689, pp. 357—358, July 31st 1920—Abstract. *Elektrotechnische Zeitschrift*, 41, p. 572, July 22nd, 1920—Abstract.)

A discussion of the applicability of the ordinary telephone formulæ for calculating the attenuation constant of a line to the case of very high frequencies, in view of the variation of the resistance, inductance, capacitance, and leakance with the frequency.

1180. WIRED WIRELESS TELEGRAPHY. (*La Nature*, 48(2), pp. 93—94, August 7th, 1920.)

A short *resumé* of some of G. O. Squier's work on Wired Wireless.

1181. INTERPLANT TELEPHONE COMMUNICATION ESTABLISHED OVER HIGH TENSION WIRES. (*Electrical World*, 76, p. 141, July 17th, 1920. *Technical Review*, 6, p. 788, September 28th, 1920—Abstract.)

Refers to an installation of wired wireless telephone over the high tension power lines of the American Gas and Electric Company. Range of transmission about 21 miles.

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* See RADIO REVIEW Abstract No. 322, April, for Part I.

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2. Books.

Éléments de Télégraphie sans Fil Pratique. By F. Duroquier. (Paris: *H. Dunod.* Second edition, 1920. Pp. 130. Price, 6 fr. 75.)

This is a small handbook for the French amateur radiotelegraphist. It is divided into three parts, the first treating of elementary principles, the second the construction and installation of apparatus, and the third, entitled "Applications of Wireless Telegraphy," gives information about time and meteorological radio services, the Morse code and similar subjects.

In the first part, the principle of action of various instruments is described, such as the induction coil, coherer, electrolytic, crystal, and other detectors, together with the simpler circuits for transmission and reception. Included among the latter are several diagrams with the detector inserted in series with the aerial, which might just as well be omitted since they are far inferior to the more usual circuits, and are likely to give erroneous impressions as to sensitivity of detectors, etc., to the amateur who is taking up the subject for the first time. The advantage of coupled circuits is pointed out and there is a short description of a three-valve note magnifier.

The description, whilst very elementary, is, in general, correct. The author, however, wrongly attributes the invention of the aerial to Sir Oliver Lodge.

In the second part, the dimensions and other details of construction of various instruments are described, such as an induction coil, aerial, condensers and inductances. The instruments manufactured by the author are described, but are not put forward too prominently.

The principal circuits for transmitting and receiving are given, with the reasons why some are superior to others.

The use of frame and coil aerials, and of wires on the ground, telephone wires and lighting cables as substitutes, is described.

The author gives particulars of distances over which he has himself worked the sets described, and includes hints for the care and maintenance of the apparatus. The reception of continuous waves by the tikker and heterodyne methods, and the construction of a three-valve resistance amplifier, are described.

The third part is devoted to the Morse alphabet, service abbreviations, call signs of certain well-known stations. By a strange mistake (perhaps a printer's error) the S.O.S. distress signal is placed in a list of abbreviations used "by the British Post Office and the Marconi Company."

A description is given of the time and weather reports and the regulations of the French public radiotelegraphic service.

The diagrams are clearly drawn, the work is well written, and is suitable for an amateur who is beginning the study of wireless telegraphy and has not advanced to the stage of wanting to know "the reason why" of the various phenomena he encounters.

W. H. Nottage.

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INTRODUCTION À LA THÉORIE DES COURANTS TÉLÉPHONIQUES ET DE LA RADIOTÉLÉGRAPHIE. By J. B. Pomey, with a Preface by A. Blondel. (Paris: *Gauthier-Villars et Cie.* 1920. Pp. xiv + 510. Price 50 frs.)

M. Pomey is the chief telegraph engineer in the French Government service and this book is based on a course of lectures given by him to the students of the Senior Telegraph School.

Its primary object is therefore to present to such students the mathematical side of their work in order to give them an insight into the principles involved, though in many cases it is carried further than this and incorporates ideas developed by the author as a result of his own personal researches.

Only the latter half of the book deals with radiotelegraphy, the earlier part consisting entirely of the study of principles and their application to the standard problems of ordinary long distance telephony. The book commences with an introductory mathematical chapter dealing chiefly with the vector calculus necessary for the treatment of the theory which follows. The tendency of all modern mathematical physics is towards the employment of this calculus, which without doubt represents a great advance both in brevity and clearness on the old analytical methods. Unfortunately, however, but few physicists and still fewer engineers can use its method with facility; it is a subject which even in its more elementary forms has been neglected both in literature and teaching.

In this country at any rate there are very few except pure mathematicians and physicists who have a working acquaintance with three dimensional analysis on which of course such a calculus must be founded. Its chief use in this book is to prove the fundamental theorems in the three following chapters; as the problems discussed in the later ones do not in general possess more than two degrees of freedom, so that any one whose mathematical knowledge is not up to vector calculus may yet obtain a great deal of information from the later, and more practical part, of the book.

Chapters II., III. and IV. are devoted to a discussion of the fundamental theorems of electromagnetism, and though they are probably beyond the depth of the average student they contain some of the most interesting work in the book, due to the researches of the author, and to his predecessor M. Vaschy. Broadly speaking one of the leading ideas of the system is to take as the fundamental datum the idea of force, and to deduce from it the ordinary ideas of charges, etc. by a mathematical operation. For instance the charge Q on a body is defined as the integral of a vector over a surface.

Theoretically no doubt this is perfectly sound; in any science resting on a strictly logical basis it is permissible to define the fundamental principle at the most convenient point of the chain and the sequence is bound to be complete. In this way mathematical simplification can often be obtained; but it is a method which offers great difficulties to students and to many engineers. For such people the most convincing point at which to start is with an idea which appears in direct presentation or can be reached by simple analogy. It may be argued that in truth the fundamental physical presentation is that of force, but to see this requires a power of abstraction which is often not present; and tends to the less trained mind to give an idea of complexity which is not really justified. Once however, the fundamentals have been defined in this manner, they are used in subsequent investigations in a way in which they are intelligible to those who are familiar with the more usual definition. Chapter III. deals with the laws of Ohm and Laplace, and the law of induction; special attention being paid to the last in view of the methods of definition employed in the book. The theories of Maxwell and Lorenz are then dealt with. Here not so much attention is paid to the purely mathematical side; the object is rather to bring the older theories, such as the two-fluid theory and Maxwell's displacement current into line with the more modern theories of the electric field.

It is well known that modern research has profoundly modified many of the physical theories on which the earlier mathematicians based their investigations, consequently the validity and interpretation of their results is bound up with the question of how far their

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physical ideas can still be considered to hold, and what new interpretation must be placed on them.

The question of the energy of the electric field is discussed and the fact that it is possible to show from the law of induction an analogy with the mechanical principle of conservation of energy; and it is suggested that, as in mechanics, this should be taken as the fundamental datum.

With Chapter V. commences the more practical part of the book. A few pages are given to the consideration of simple harmonic functions both by the use of imaginaries and by the vector calculus. Preference is given to the latter owing to an ambiguity of sign which occurs when the former is applied to the more complex problems.

Damped oscillations are treated by means of a rotating vector tracing out a spiral, and oscillating circuits in general are treated by analogy with the corresponding mechanical problems such as the moving coil galvanometer, special attention being paid to the case in which an oscillating circuit receives periodic impulses.

The equation for the logarithmic decrement is derived in the ordinary way, and then by means of a series of curves derived from it the effect on it is shown graphically for variations of L C and R respectively the other two being kept constant. Such curves would perhaps be more useful, for wireless purposes, at any rate, if the wavelength (and hence the period) had been the constant quantity. A short chapter is devoted to networks, and then a general investigation of the power, both actual and wattless, in such networks is undertaken by means of the vector calculus. The results are interesting theoretically but in the general form are rather elaborate and heavy for practical application.

Chapters XI. and XII. are devoted to a very full development of the work of Pupin on which of course the loading of modern telephone lines is based, and to its application; showing how all the necessary determinations can be made in any particular case.

Chapter XIV. treats in full what is often known as the telegraph equation; the law of propagation of a current along a finite cable under various different terminal conditions, which is solved mathematically. It is then shown that the same results can be obtained in another way, by representing the line as a series of circuits forming a network, and by then indefinitely increasing this number. In this way a great deal of calculus can be avoided.

The consideration of radiotelegraphy proper does not commence until Chapter XV. which is devoted to the question of the mechanical problem of the aerial wire and involves the ordinary catenary equations; the latter part dealing with the strength of the supporting masts.

The electrical constants of the aerial are treated by direct analogy with the vibrating string the equations of which are derived by means of Lagrange's equations and which are then converted directly to the electrical problem by changing the names of the quantities involved. Attention is drawn to the point, so often neglected that the loading of an aerial by an inductance at one end really causes a discontinuity in the constants so that reflections occur and the oscillation is no longer pure and simple.

After a discussion on the resonance of the primary circuit of a transmitter the theory of the spark discharge, the high frequency alternator and the Duddell arc is considered; but the thermionic valve is not dealt with.

The final chapters are devoted to the solution of the problems dealing with the theory and measurement of capacity and self-induction. The book is an excellent attempt to solve the almost impossible problem of presenting to the practical man the fundamental theory of his subject, but the crucial point arises as usual over the mathematics. For instance Lagrange's equations are a *terra incognita* to the majority of such people, and anybody who was not thoroughly familiar with the calculus would find himself baffled very quickly, though no doubt when given as lectures many points were enlarged upon in a manner which it is not possible to reproduce in print and in this way many such difficulties were bridged.

In the general arrangement of the book a most excellent plan which ought to be widely copied is the giving at the commencement of each chapter a short summary of the problems which will be discussed in it in detail.

J. Hollingworth.

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WORKING DIAGRAMS OF VALVE AMPLIFYING RECEIVER CIRCUITS. H. W. Sullivan. (London: *H. W. Sullivan.* 1920. Pp. 24. Price 1*s.*)

The working diagrams inserted in this booklet have been selected for their simplicity, and easy application to practical working. They are intended chiefly for use in conjunction with the catalogue of wireless instruments issued by the same firm, and with this in view, the parts of the diagrams have been numbered to correspond with the numbering adopted in the catalogue. The diagrams seem to be well chosen, and should be useful both for amateurs and experimenters, and in college and similar laboratories.

P. R. C.

Books Received.

ELECTRON TUBES—Langmuir's Record in *Arnold* v. *Langmuir.* (Interference No. 40,380 in the U.S. Patent Office. 1920. Pp. 969.)

This highly interesting volume contains a very detailed account of the action of thermionic devices as given in evidence by Langmuir and his assistants at the General Electric Company at Schenectady.

ELEMENTS OF RADIO TELEGRAPHY. By E. W. Stone, M.Inst.R.E. (New York: *D. Van Nostrand Co.* London: *Crosby Lockwood & Son.* 1920. Pp. vii + 267. Price 16*s.* 6*d.* net.)

VOCABULAIRE EN CINQ LANGUES. By H. Viard. (Paris: *Gauthier Villars et Cie.* 1920. Pp. x + 108. Price 7 fr. 50.)

Correspondence.

TRIODE VALVE DESIGN.

To the Editor of the RADIO REVIEW.

SIR,—In the review of a paper "The Development of Thermionic Valves for Naval Uses," by B. S. Gossling, in the August RADIO REVIEW, the formula

$$m = \frac{\pi N d' \log (d/d')}{\log (1/\pi N d_g)}$$

is given for the amplification factor of a cylindrical valve. If this result is differentiated with respect to d' and $\partial m/\partial d'$ equated to zero, the result obtained is $\log d/d' = 1$, or $d/d' = \epsilon = 2{\cdot}72$.

Therefore if d, d_g and N are fixed m has a stationary value and is a maximum when $d/d' = 2{\cdot}72$.

Hence, in designing valves there is some advantage in making $d/d' = 2{\cdot}72$, for with such a value variations of m due to slight errors in d/d' caused by inaccurate centring of the filament and errors in d and d' themselves, will be minimised. It is interesting to note that many types of receiving valves fulfil this condition very closely.

A. C. BARTLETT.

Research Laboratories of the General Electric Co., Ltd.,
London,
October 5th, 1920.

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THE
RADIO REVIEW

VOL. I DECEMBER, 1920 NO. 15

Phenomena in Oxide-coated Filament Electron Tubes.*

By H. D. ARNOLD.

The most generally interesting phenomena in electron tubes are those relating to the flow of electrons through the space, the control of the flow by plate and grid voltages, and the operation of the tubes in the various circuits in which they are used. These phenomena are essentially the same whether the filament is pure metal or is oxide-coated and a considerable literature has already grown up in this field. The phenomena distinctive of oxide-coated filament tubes are those relating to the economic and scientific factors involved in the process of electron emission and the influence of these factors on the design of the tube. Wehnelt oxide filaments offer the most economical source of electrons at present available in three-electrode vacuum tubes, and thus from a commercial point of view they are at present of the greatest interest and importance.

The early work of Richardson, H. A. Wilson and others established beyond reasonable doubt that for pure metals the emission of electrons is due to thermal action and not to chemical action in the ordinary sense of the word. In view of this physicists have believed for the past ten years or more that there was no place for a chemical theory of emission as far as pure metals are concerned.

With respect to Wehnelt oxides, however, there was somewhat less certainty as to whether chemical action might not be necessary for electron emission. The fact that coating metals with chemical compounds increased their electron emission many times seemed to invite the hypothesis that this increase resulted from chemical action.

Data similar to those which established the purely thermal nature of electronic emission from metals were accumulated more slowly in the case of Wehnelt oxides, largely because of the experimental difficulties which were encountered. As regards the velocity distribution among the emitted electrons, this has still to be satisfactorily determined for the oxides, but nevertheless the evidence as it has been verified step by step has in every case supported the opinion of the physicists who believed that emission from oxides as well as metals was in all probability a purely thermal affair.

* Abstracted from the *Physical Review*—see Abstract No. **1226** in this issue.

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With the introduction of oxide filaments for commercial vacuum tubes it became necessary to produce filaments in quantities and with a very high degree of uniformity. Considerations of mechanical strength, electrical resistance, non-oxidizability, availability and reproducibility of commercial supply, etc., led to the choice of a wire of platinum-iridium alloy containing about six per cent. iridium for the core of the filament. This wire was rolled to a ribbon to increase the surface and the ribbon was twisted to secure a better mechanical structure. This core could be produced in quantity with electrical and mechanical properties sufficiently uniform for the required purposes.

In the choice of coating materials the oxides of barium, strontium and calcium were available, their thermionic activities being in the order given. Coatings of barium oxide however showed a mechanical disintegration which outweighed their superior activity. Efforts to secure a longer life resulted in the use of a mixture of barium and strontium oxides applied in a number of consecutive coatings.

In the process which was most commonly used, barium in the form of carbonate, and strontium in the form of hydroxide or carbonate, were mixed with some carrier such as resin or paraffin, which would burn away when heated in the air. In the coating process four applications of the strontium mixture were followed by four of the barium mixture, and this process was then repeated making a total of sixteen separate applications. After each application the wire was raised momentarily to a temperature of about 1000°, which burned away most of the organic carrier. When the coating was complete the wire was heated to about 1200° for two hours. At the end of this time there remained a fairly heavy coat of barium and strontium (from 2 to 3 milligrams per square centimetre of surface) while next to the core was a firmly adhering layer built up by chemical reactions between the coating and the core. Analysis showed this coating to consist of barium and strontium combined with platinum, rhodium and iridium, the compound present in largest amount being barium-platinate ($BaPtO_3$). The compound with rhodium seems to be more readily formed, but due to the small percentage of rhodium present this compound makes up only a small fraction of the total. The filament thus formed can be handled without undue precaution so long as it is not exposed to moisture or carbon dioxide. When stored in vacuum containers it shows no signs of deterioration even after a period of several years.

The time required for the proper evacuation of an oxide filament tube is determined almost entirely by the requirement that a large part of the occluded gases must be removed from the metal and glass parts inside the bulb. In any event it is desirable to carry the evacuating process considerably further in the case of oxide filament tubes than with tungsten filament tubes, since the "clean-up" effect of the filament itself is not nearly so marked as is the case with tungsten. During the pumping process the filaments are glowed for several minutes to liberate any occluded gases.

With the exercise of proper care as to the purity of the materials used and with adherence to a definite schedule of coating and heat treatment

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filaments can be produced with every expectation of uniformity and long life. During the war some half million vacuum tubes were made employing this filament, and the filament was prepared as a part of the regular manufacturing process by practically unskilled labour.

What terminates the useful life of an oxide filament is usually the development of local faults or " bright spots " due to the evaporation of the coating. They are practically free from the most common ageing effect of pure metal filaments, namely the gradual increase of electrical resistance caused by the evaporation of the filament. In the case of tungsten filaments used on constant voltage supply, evaporation with the resulting increase in resistance causes a lowering in the filament temperature and therefore a decrease of the electron emission, while with a constant current supply the increase in resistance results in an increase of temperature and a progressive increase in rate of disintegration of the filament. With oxide-coated filaments it is the coating alone that evaporates at least until a bright spot is formed and the temperature and operating characteristics remain unchanged throughout life on either constant current or constant voltage supply.

The cost of electrons in a vacuum tube device is determined by the characteristics of the filament, by the cost of the power used in heating the filament, and by the life and the replacement cost of the tube. The physical factors necessary for computing the cost are the constants in Richardson's equation, the constants of the evaporation equation, and the radiation constant peculiar to the filament. In order to relate the life of the tube to the vaporization constants it is necessary in addition to know to what extent vaporization may proceed on the average, before the useful life is terminated, and this can, of course, only be arrived at by exhaustive life tests.

The preliminary values of the evaporation constants obtained by evaporating barium oxide from a tungsten boat, catching it on a platinum shield, and weighing the deposit show that with a fair approximation

$$m = 4{\cdot}6 \times 10^{8} \cdot T^{-\frac{1}{2}} \epsilon^{-[(4{\cdot}6 \times 10^{4})/T]}$$

where m is the rate of evaporation in grams per square centimetre per second.

In the determination of the constants in Richardson's equation for oxide filaments over 4,000 filaments have been examined in the Western Electric Company's laboratories. In order to simplify the investigation it has been found desirable to employ a specially ruled paper on which the results may be plotted. The co-ordinate lines are so disposed and numbered that if the emission from a filament satisfies Richardson's relation and the thermal radiation satisfies the Stefan-Boltzmann law, then the points on the chart co-ordinating power and emission for such a filament will fall in a straight line. The diagram (Fig. 1) gives some idea of the characteristics of the standard filaments which have been evolved, and their range of variability. Ten per cent. of the filaments had a greater activity than that given by the upper line, while 90 per cent. were above the lower line in the diagram. It may be noted that in the great majority of vacuum tube applications we are concerned only in maintaining the electron emission at a value greater

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than a certain fixed limit. In a limited number of cases, however, it is desirable to use tubes with as nearly as possible the same voltage saturation value of the emission. For these special problems pure metal filaments offer at present the best solution.

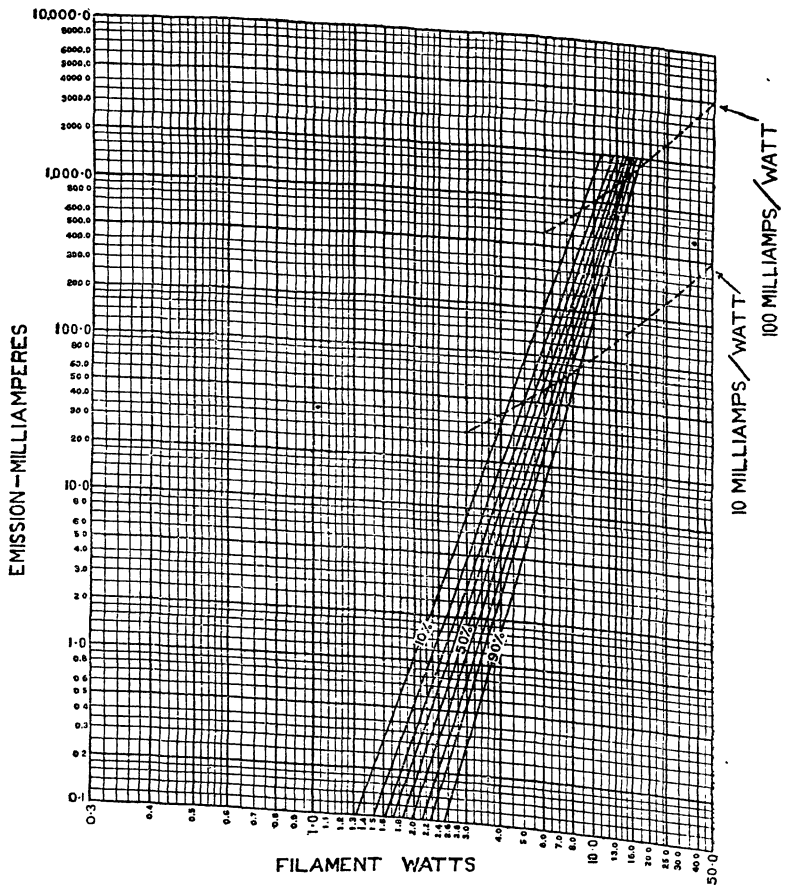

FIG. 1.—Chart showing average characteristics of standard Western Electric Oxide-coated Filament, based on tests of 4,301 samples, April to October, 1918.

The customary operating power of these filaments is from 8 to 9 watts per square centimetre. From the test results the following values are obtained for the thermionic characteristics of the filament:

Richardson's constant b, $19{\cdot}4 \times 10^3$ to $23{\cdot}8 \times 10^3$.
Richardson's constant a, $0{\cdot}5 \times 10^{24}$ to $1{\cdot}5 \times 10^{24}$ for electrons per second per square centimetre;
or 8×10^4 to 24×10^4 for amps. per square centimetre.

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Dr. W. Wilson has found that when proper consideration was taken of the geometrical form and of the voltage drop along the filament, the space charge equation took the form

$$i = \frac{2}{5} k \frac{(V - V_0')^{5/2}}{V_0 - V_0'} \left[1 - \left(1 - \frac{V_0 - V_0'}{V - V_0'}\right)^{5/2}\right]$$

where V_0' is the potential of the negative end of the filament and V_0 the potential of the positive end. The value of e/m obtained from the experimental data by the use of this equation was found under the best conditions to be about 5 per cent. lower than the value obtained for electrons by other methods. This deviation is explicable either by the presence of a very small number of negative carriers of molecular size or by the emission of secondary electrons from the anode under the bombardment of the primary electrons. The deviation is however, no greater than that obtained with tungsten filaments, and the concordance of the results indicates clearly that Wehnelt oxides may be considered to give a pure electron discharge.

With the introduction of various gases at pressures of the order of 0·001 mm, or so, the electron emission currents suffer rather large changes, although not of the degree found with the emission from tungsten filaments under similar conditions. The presence of oxygen and carbon dioxide inhibits the electron emission while a small amount of hydrogen in contact with a filament of abnormally low emission may result in restoring it to a normal condition.

In recent experiments it has been found of great convenience to use filaments which have been coated by active material evaporated from a standard filament. The standard filament and the wire to be coated are mounted close together in the same tube and the primary is run at a fairly high temperature for various lengths of time according to the purpose of the experiment. Observations are then made on the emission from the secondary filament. One advantage of this method of experimentation is that the core of the secondary filament may be any suitable material, for example tungsten or iron, without meeting the difficulties of oxidation, which are often troublesome when these materials are coated in the open air.

These secondary filaments have many interesting properties which no doubt will prove of importance in establishing the process of electron emission from Wehnelt oxides. One of the most striking facts is that the secondary filament may show a high electron emission when only a very minute amount of active material has been transferred to it. In certain experiments where the secondary filament was tungsten, the standard filament was glowed for so short a time that only approximately one-tenth of the surface of the tungsten filament was covered with active material.

It is most interesting to note that the electron current obtainable at a given temperature from filaments coated in this very tenuous fashion may be only a little smaller than that obtained when the entire filament is covered with a heavy deposit.

It is natural to ask whether this result is due to a difference in the a or in the b of Richardson's equation as applied to these partly coated filaments.

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Measurements of b taken at intervals while the deposit was forming have never shown an increase with thickness of deposit, and therefore it seems that the result must be due to a difference in a. If we assume that a completely coated filament emits uniformly over its entire surface while a partly coated filament emits only in the vicinity of the molecule of active material, we compute an a for the partly coated filaments which is much greater than the values ($0{\cdot}5 \times 10^{24}$ to $1{\cdot}5 \times 10^{24}$) given above for the standard filament. The fact that the b obtained for filaments coated merely with a few widely separated molecules is the same as that obtained with a complete coating shows that the reduction of the work function at the metal surface can be brought about by a very small group of molecules. Under these conditions it seems reasonable to suppose that the only important effect of the molecule of active material is to lower the restraining voltage in its own vicinity and thus facilitate the passage of electrons from the metal core. The number of electrons that can avail themselves of such a molecular opening is limited to those presenting themselves with a sufficient outward velocity, and this in turn is determined by the properties of the core material. Since the core materials used have values of a greater than those which we find for the standard filaments it does not seem so strange that the values of a for the partly coated filaments should be found to run higher than those for completely covered filament.

We hope that our present experiments will throw more light on the factors involved in the escape of electrons through these minute activated areas. Our information is at present too meagre to warrant an opinion as to whether an electron on its way out remains for some time as a part of the molecule of active material or merely slips past it. The number of electrons passing but through one molecular opening in a second may be of the order of ten thousand and that this rate may persist for some time is indicated by the rather slow rate of decay of activity. This proves at least that no irreversible chemical change in the active coating is involved in the emission of an electron. Perhaps a more striking proof of this is found in certain of these filaments which through a life of twenty thousand hours have emitted fifteen times more mass of electrons than the mass of their coating.

Another factor of importance in connection with the use of Wehnelt oxides is the velocity with which they emit electrons when bombarded. Such secondary emission may be comparatively large when they are bombarded by electrons, but there is no evidence of more than a few electrons being emitted for each impact of a positive ion. This negatives the idea that positive ion bombardment is a controlling factor in the emission from oxide coated filaments.

The limit to which the improvement in the emission qualities of electron tube filaments may be expected to extend can only be determined when the factors governing electron emission from oxides are as well understood as are at present those governing electron emission from pure metals. It is more than probable that in the process of obtaining this knowledge new light will be thrown upon the process of emission from pure metals as well.

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An American Duplex Radiotelephone Set.*

By M. B. SLEEPER.

The question of two-way radiotelephony in which two speakers may carry on a conversation without the necessity of changing the circuit connections from receiving to sending, or *vice versa*, and which is commonly referred to as "duplex radiotelephony," is one which has interested radio engineers for some time past.† While many attempts have been made to obtain successful duplex working it has not yet by any means come into general use. This is no doubt due largely to the enormous ratio between the power in the transmitter and the energy received from the distant station. Hence it has been necessary in most commercial radiotelephone apparatus to use some form of switch or key for throwing over from speaking to listening, the set normally being in the condition for reception and being thrown over to transmission only during the actual speaking period, during which time the local receiving circuit is entirely disconnected.

The Western Electric Company (U.S.A.) have recently designed and built duplex radiotelephone sets for the United States Navy which permit two people to converse together by radio without the necessity of throwing switches and with no more thought to the question of whether the other is transmitting or receiving than in the case of an ordinary wire telephone conversation.

A number of different arrangements are possible for duplex radio signalling. One method is obviously to employ two separate antennæ, one for transmitting and one for receiving, the two being tuned to different wavelengths and so disposed relative to each other that the receiving antenna is not appreciably affected by its own transmitting station. This is particularly convenient if the receiving and transmitting stations can be separated by a distance of a few miles and connected together by land wires. Another method is to employ a single aerial only for both transmitting and receiving with the addition of some balancing arrangement to reduce the amount of power from the transmitter which enters the receiving circuits.

Where space is restricted such as on ships the first method cannot be used and the second offers the only satisfactory solution to the problem provided that the balancing of the circuits can be effected with sufficient accuracy. Some years ago experiments were conducted by the U.S. Navy using the first of these two methods at land stations, and successful communication was established between Washington and installations on battleships at sea. The arrangement of the latest sets built by the Western Electric Company

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* Abstracted from *Everyday Engineering Magazine*—see Abstract No. **1216** in this issue.

† The application of duplex radiotelephony to aircraft was recently discussed by Captain P. P. Eckersley in a paper read before the Wireless Section of the Institution of Electrical Engineers. An abstract of this paper will be found on pp. 338—340 and pp. 383—385 in our issues of April and May, 1920.

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for duplex working may be seen from the circuit diagrams of Figs. 1 and 2. Fig. 1 is a simplified diagram of connections of the transmitting unit which unit may also be seen on the left-hand side of Fig. 3. Two three-electrode tubes are employed, one of which acts as an oscillation generator and the other

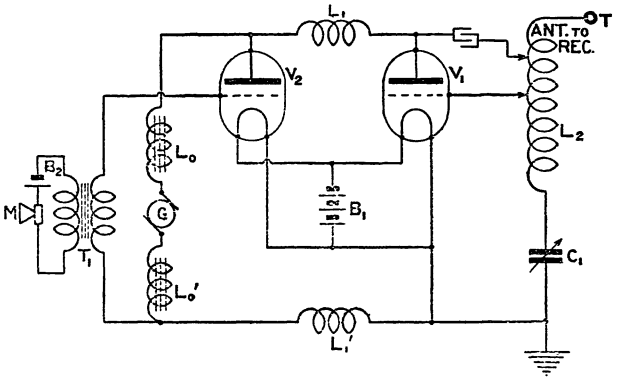

FIG. 1.—SIMPLIFIED CONNECTIONS OF TRANSMITTER.

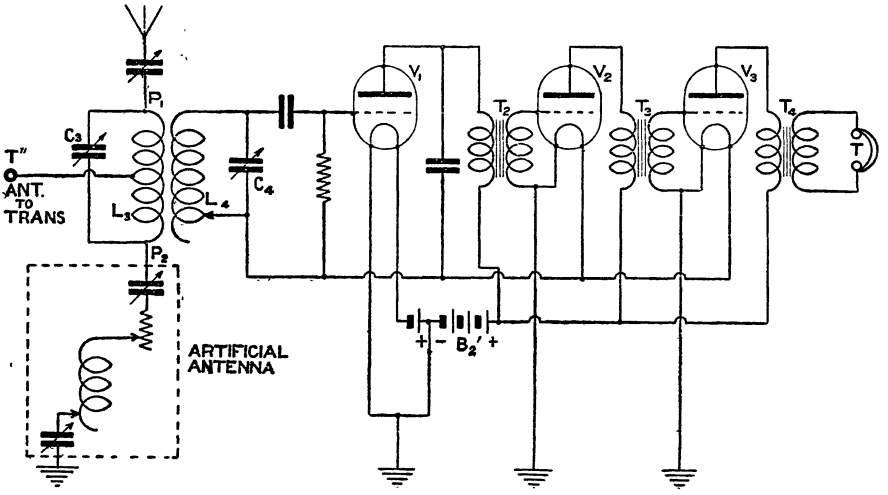

FIG. 2.—GENERAL ARRANGEMENT OF RECEIVER AND ARTIFICIAL ANTENNA.

as a modulator. The particular circuit used in this set is that commonly referred to in America as the "Colpitts Circuit." It consists briefly of a tuned circuit having two capacities in series, one being in shunt to the plate circuit and the other to the grid circuit of the tube. In this instance the coil L_2 forms the inductance of the tuned circuit, C_1 is the condenser in the

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(To face p. 752.)

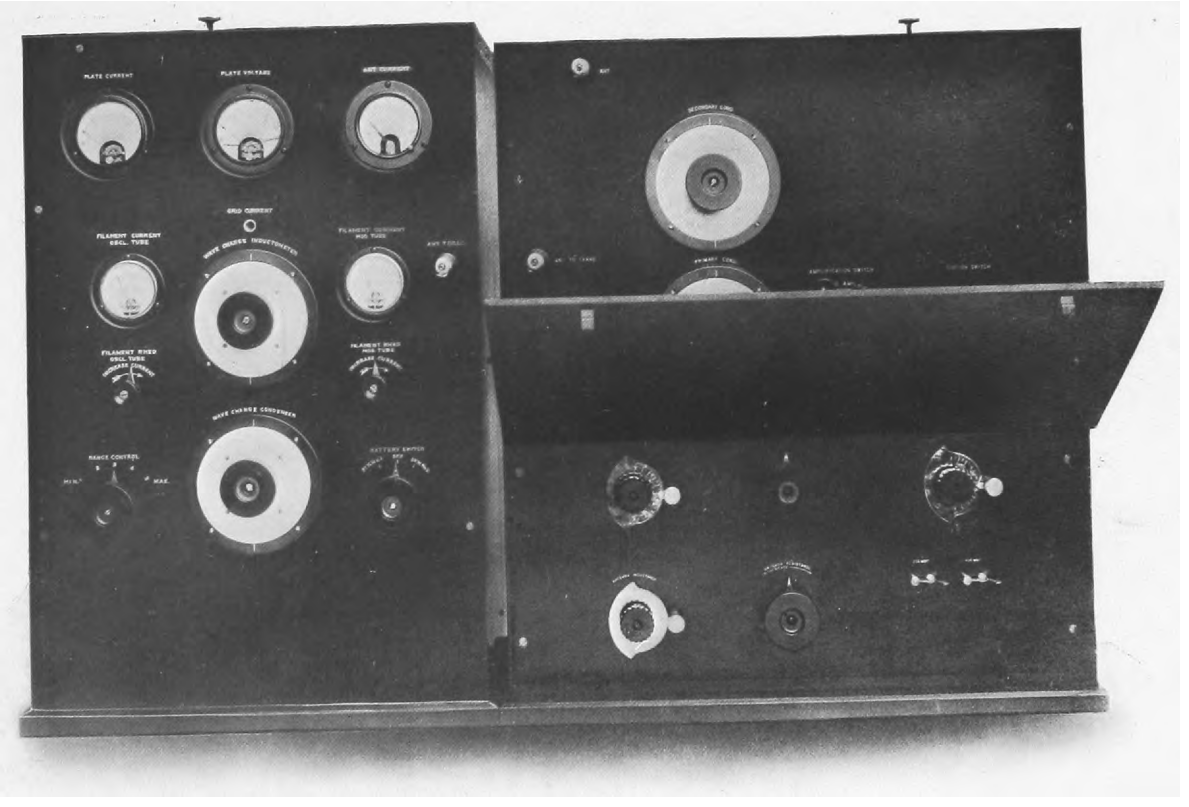

FIG. 3.—GENERAL VIEW OF DUPLEX RADIOTELEPHONE (WESTERN ELECTRIC CO., U.S.A.).
Transmitter Unit on left; Receiver and Artificial Antenna on right.

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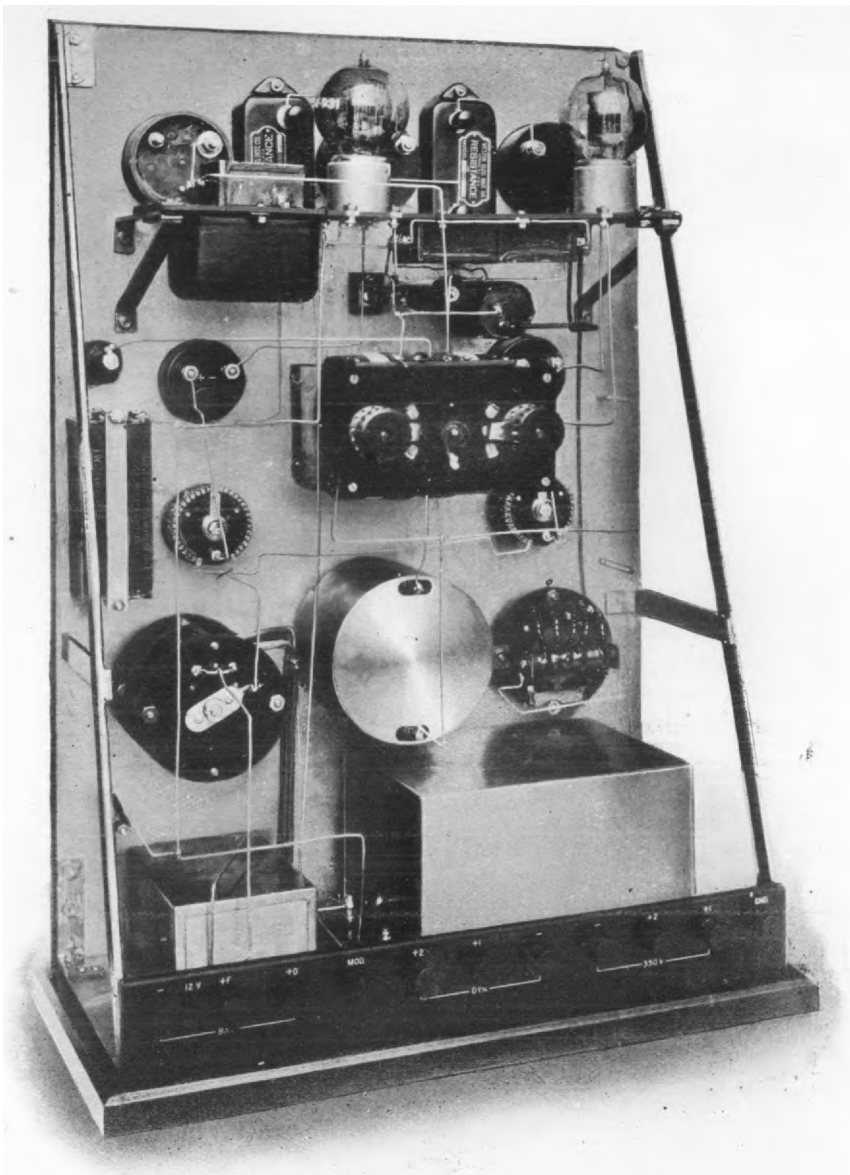

FIG. 4.—REAR VIEW OF TRANSMITTER UNIT.

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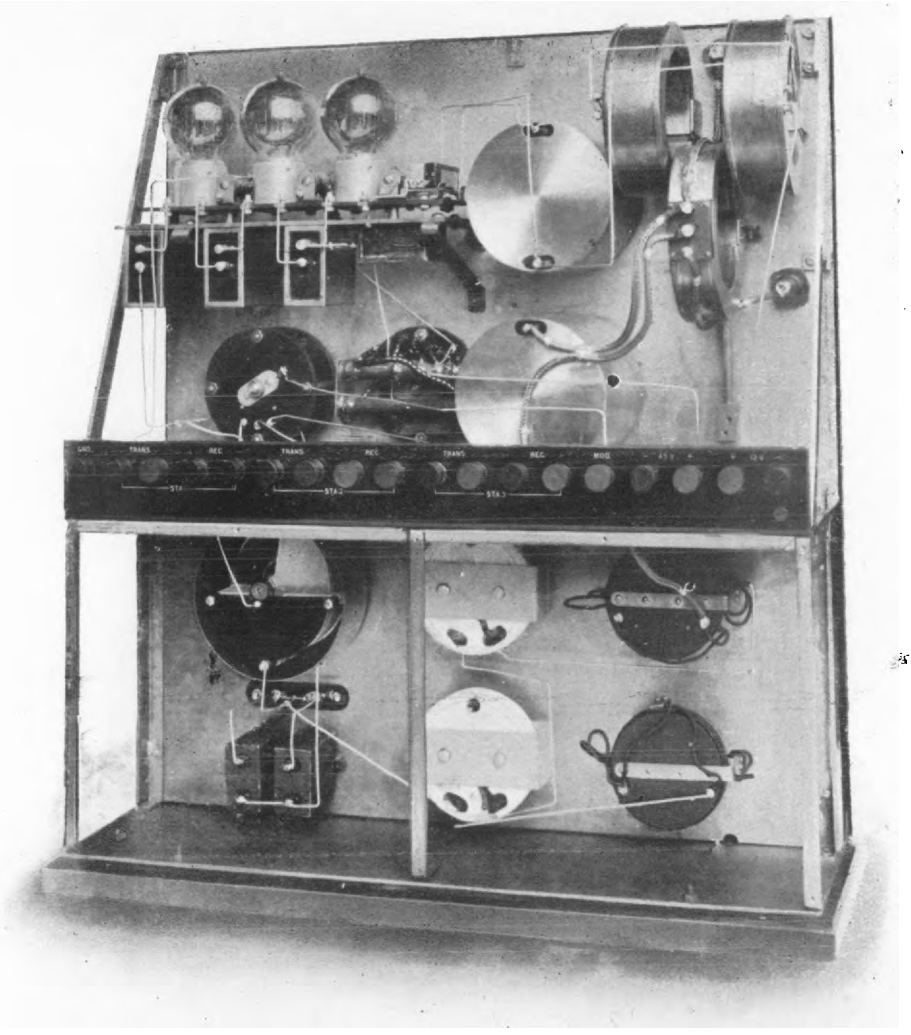

FIG. 5.—REAR VIEW OF UNIT CONTAINING RECEIVER, AMPLIFIER AND ARTIFICIAL ANTENNA.

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grid circuit and the capacity of the aerial system to earth is in shunt to the plate circuit. The filament is connected to the common point between the two capacities, in this case the earth connection. Power is supplied to the plate circuits of the tube by the generator G. The oscillations set up by the oscillating valve V_1 are modulated by the tube V_2 by the method often referred to as "choke control," suitable choking inductances L_0L_0' and L_1L_1' being inserted in the position shown. The modulator tube V_2 is controlled by the transmitting microphone M through the coupling transformer T_1. The modulator tube therefore acts as a variable shunt to the oscillating tube, and this controls the amplitude of the oscillations that are radiated. The terminal T' shown in Fig. 1 corresponds to that marked **ANT. to REC.** in Fig. 3. When the instruments are in use this terminal is joined to the adjacent one on the right-hand unit in Fig. 3 which is marked **ANT. to TRANS.**

A simplified circuit diagram of the receiver unit which is on the right-hand side of Fig. 3, is given in Fig. 2. In this circuit the inductance L_3 and condenser C_3 constitute the tuned circuit which by varying the condenser C_3 can be tuned to the signalling frequency. Associated inductively with this coil is a second tuned circuit L_4C_4 which is connected directly to the grid circuit of the detecting valve V_1. The plate circuit of this tube is coupled through transformer T_2 to the two-stage amplifier indicated at $V_2T_3V_3T_4$, the secondary circuit of the last transformer T_4 containing the telephone receivers T. The plate circuits of all the receiving tubes are supplied from the common battery B_2'. The connection to the transmitting apparatus is made from the mid-point of the coil L_3 *via* the terminal T'' which corresponds to the terminal marked **ANT. to TRANS.** of the right-hand unit shown in Fig. 3. The right-hand unit in Fig. 3 contains the receiving apparatus in its upper part and the artificial balancing antenna in its lower part. This artificial antenna is joined between the point P_2 and earth (Fig. 2). The oscillatory current from the transmitter therefore divides equally through the coil L_3, one half flowing into the antenna and the other half through the artificial antenna. The points P_1 and P_2 are thus always at equal potentials as regards the transmitter. Oscillations received on the aerial, however, are not so balanced and will therefore produce an effect in the telephones. The artificial antenna must be made to imitate as closely as possible the actual antenna both in oscillation and in damping characteristics.

A rear view of the two units is shown in Figs. 4 and 5 from which the general arrangements of the parts of the apparatus may be seen.

When required for aircraft use it has been found more convenient to divide the receiving unit (Fig. 5) into two parts containing respectively the actual receiver and the artificial antenna. The latter may then be mounted in a less accessible position so as not to interfere with other instruments on the machine.

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A Theory of the Amplitude of Free and Forced Triode Vibrations.

By BALTH. van der POL, Jun., D.Sc.

(*Continued from page 710, November, 1920.*)

We shall now consider a little more in detail the amplitude of the generated oscillations.

Let AB (Fig. 8) be an $i-v$ diagram constructed for a certain positive value of $k = g\frac{M}{L} - 1$ as explained in section 2 and Fig. 3.

In order to simplify the discussion we take a symmetrical characteristic, *i.e.*, one for which the unimportant factor $\beta = 0$. Let further the equation of AB be

$$i = -\alpha v + \gamma v^3$$

where both $\alpha > 0$ and $\gamma > 0$.

Draw COD such that $\tan \xi = -\frac{1}{R}$.

The tangent FG at AB in O gives $\tan \zeta = -\alpha$.

From (20) it is seen that as long as $\tan \zeta > \tan \xi$ or $\zeta > \xi$, *i.e.*, as long as CD cuts the characteristic AB, oscillations will be possible. Now from the

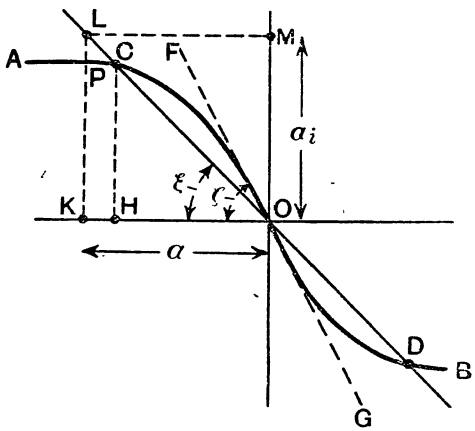

FIG. 8.

equations for AB and CD namely

$$i = -\alpha v + \gamma v^3$$

and

$$i = -\frac{1}{R} v$$

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we find the abscissa OH of C to be

$$\mathrm{OH} = \sqrt{\frac{\alpha - \frac{1}{R}}{\gamma}}$$

Hence the amplitude OK of the maintained oscillations

$$\left(a = \sqrt{\frac{4}{3}\frac{\alpha - \frac{1}{R}}{\gamma}}\right)$$

is obtained by multiplying the length of OH by $\frac{2}{\sqrt{3}} = 1{\cdot}155$.

The oscillations therefore extend beyond the point C where the resistance curve CD cuts the characteristic, while the fundamental anode-current amplitude OM equals $\frac{1}{R}$ times the fundamental P.D. amplitude OK, and can be constructed simply as indicated in the figure by extending KP till it cuts OL at L.

A further physical investigation of the amplitude of the vibrations necessary for them to reach the steady state may be obtained from the following considerations.

From (I.[a, b]) it follows, with $\frac{di}{dt} = \frac{d\psi}{dv}\frac{di}{dt}$ that the oscillations must satisfy the equation

$$\frac{d^2v}{dt^2} + \frac{1}{C}\left(\frac{1}{R} + \frac{d\psi}{dv}\right)\frac{dv}{dt} + \frac{1}{CL}v = 0.$$

where $\frac{1}{C}\left(\frac{1}{R} + \frac{d\psi}{dv}\right)$ is the damping coefficient which, in our case, is a function of the amplitude. Referring to Fig. 8 let the curve AB represent $i = \psi(v)$ and as before let $\tan\xi = -\frac{1}{R}$, then the function $\frac{1}{C}\left\{\frac{1}{R}v + \psi(v)\right\}$ may be

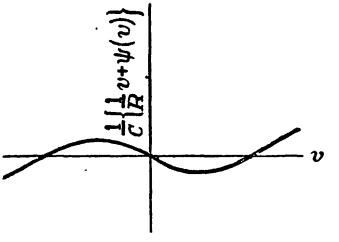

FIG. 9.

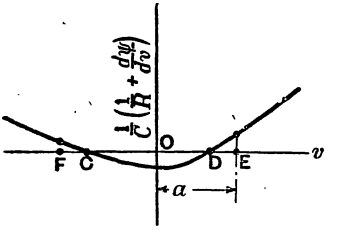

FIG. 10.

constructed from Fig. 8 as indicated in Fig. 9; the next step is to differentiate this last function (of Fig. 9) and thus obtain Fig. 10.

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Now the ordinates of Fig. 10 give the damping coefficient (the coefficient of the $\frac{dv}{dt}$ term in the differential equation) as a function of the amplitude of the oscillations. As long as the amplitude is smaller than OD the damping coefficient is negative over the whole period, and hence the oscillations will tend to increase. Even when the amplitude has reached OD the damping coefficient over the whole period is still negative and the oscillations will go on still further to increase. But when a certain point beyond OD is reached, such as E, the amplitude will be stationary, as during a part of one complete oscillation the damping factor is negative while over the other part it is positive. That finally the case referred to above, where

$$\alpha - \frac{1}{R} < 0$$

$$\gamma < 0$$

does not allow a stable oscillation to be set up is obvious from the fact that the damping factor, being again a function of the amplitude, is here of the form of Fig. 11.

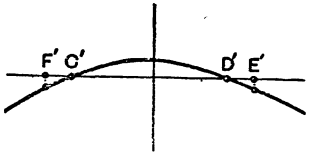

FIG. 11.

For, when the amplitude OE is reached, a slight increase of the latter would make the damping factor negative over a greater part of the period with the result that the amplitude would increase indefinitely.

7. In order to find an approximate value for the stationary amplitude of the fundamental of an oscillating triode, it is not necessary for the derived characteristic to be developable as

$$i = -\alpha v + \beta v^2 + \gamma v^3.$$

For, if we take the general case, where the steady anode-current—anode voltage characteristic is given as $i_{a_0} = \phi(E_{a_0})$ the function $i = i_a - i_{a_0} = \psi(kv)$ becomes

$$i = \phi(E_a - kv) - \phi(E_a) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

Now applying again the method of section **5**, we have

$$\frac{1}{T}\int_0^T ivdt + \frac{1}{R}\frac{1}{T}\int_0^T v^2 dt = 0$$

which, with the assumption $v = a \sin \omega t$, becomes

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$$\frac{a^2}{2R}+\frac{1}{2\pi}\int_0^{2\pi} a\sin t\,\{\phi\,(E_a-ka\sin t)-\phi\,(E_a)\}\,dt=0$$

or

$$\frac{a}{2R}+\frac{1}{\pi}\int_{-1}^{+1}\frac{\phi\,(E-kay)\,.\,y\,.\,dy}{\sqrt{1-y^2}}=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

from which an approximate value of the amplitude a might be obtained, when the function ϕ is known.

8. The question may be raised: What is the maximum amplitude to be obtained for a given triode and given circuits by varying M, the back coupling? From the derived characteristic

$$i=-\alpha v+\beta v^2+\gamma v^3$$

we found for the square of the amplitude

$$a^2=\frac{4}{3}\frac{\alpha-\frac{1}{R}}{\gamma} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

where

$$\alpha=k\left(\frac{\partial i_a}{\partial v_a}\right)_{v_a=E_a}$$

and

$$\gamma=-\frac{k^3}{6}\left(\frac{d^3 i_a}{dv_a^3}\right)_{v_a=E_a}$$

After differentiating (20) with respect to $k=\left(g\frac{M}{L}-1\right)$ and putting $\frac{da^2}{dk}=0$ we find

$$\gamma\frac{d\alpha}{dk}-\left(\alpha-\frac{1}{R}\right)\frac{d\gamma}{dk}=0$$

which leads to the condition for the back coupling M:

$$\frac{2}{3}\alpha=\frac{1}{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

or

$$\left(g\frac{M}{L}-1\right)h_a=\frac{3}{2}\frac{1}{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

while a^2_{max} becomes

$$a^2_{max}=\frac{4}{9}\frac{\alpha}{\gamma} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

It was seen above that with a gradual increase of M from $M=0$, the system started oscillating, though originally with very small amplitude, as

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soon as M had reached the value M_0 given by

$$\left(g\frac{M_0}{L}-1\right)h_a=\frac{1}{R}$$

If therefore *e.g.* M is left at this value M_0, and we decrease the damping to $\frac{2}{3}$ of its original value, we may (from (26)) expect the system to vibrate with the maximum amplitude possible. However, there is some uncertainty whether the power series for the characteristic is still valid for such big amplitudes. As far as our theory goes it would follow that the maximum amplitude possible by varying the back coupling would be independent of the damping of the circuit as long, at least, as (25) can be satisfied.

9. Moreover, the question as to the maximum amplitude obtainable, may be solved by starting from the general derived characteristic of (23).

For, after differentiating (24) with respect to k and putting $\frac{da}{dk}=0$, we find for the condition of maximum oscillations:

$$\int_{-1}^{+1}\frac{d\phi\,(E-kay)}{d\,(E-kay)}\cdot\frac{y^2\,dy}{\sqrt{1-y^2}}=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

Hence, generally from (28) together with (24) the maximum value of a may be obtained, as well as the necessary value of M.

10. It remains to be considered how the triode vibrations gradually reach the finite stationary amplitude discussed above. To this end we multiply (I.[8]) with $\int_0^t v\,dt$, and again consider the derived characteristic to have the form:

$$i=-\alpha v+\beta v^2+\gamma v^3$$

we thus obtain

$$C\frac{d^2v}{dt^2}\cdot\int_0^t v\,dt+\left(\frac{1}{R}-\alpha\right)\cdot\frac{dv}{dt}\cdot\int_0^t v\,dt+\frac{1}{L}\,v\cdot\int_0^t v\,dt+$$
$$+\beta\frac{d(v^2)}{dt}\cdot\int_0^t v\,dt+\gamma\frac{d(v^3)}{dt}\cdot\int_0^t v\,dt=0 \quad . \quad . \quad (29)$$

Again, assuming v to be of the approximate form

$$v=a\cos\omega t$$

where now a is a gradually varying function of t (as a first approximation ω is kept independent of t) we substitute this expression for v in (29). The equation thus obtained consists of two kinds of terms, one varying slowly and the other rapidly with t. Retaining only the terms which vary slowly, or what amounts to the same thing, taking the mean over one period of the terms of equation (29), we obtain the approximate equation

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$$\frac{1}{4}C\frac{d(a^2)}{dt}+\left(\frac{1}{R}-\alpha\right)\frac{a^2}{2}+\frac{1}{4L\omega^2}\frac{d(a^2)}{dt}+\frac{3}{8}\gamma a^4=0 \quad . \quad . \quad (30)$$

Now (30) may be written approximately

$$\left(\frac{1}{R}-\alpha\right)a^2+\frac{3}{4}\gamma a^4+C\frac{d(a^2)}{dt}=0$$

the solution of which is

$$a^2=\frac{\alpha-\frac{1}{R}}{\frac{3}{4}\gamma}\cdot\frac{1}{1-\text{const. }\epsilon^{-\left(\frac{\alpha-1/R}{C}\right)t}} \quad . \quad . \quad . \quad . \quad . \quad (31)$$

The final value $\frac{4}{3}\frac{\alpha-\frac{1}{R}}{\gamma}$ is therefore reached asymptotically, though not according to a simple exponential law.

II.—THE BEHAVIOUR OF A TRIODE SYSTEM UNDER AN IMPRESSED SINUSOIDAL E.M.F.

11. Let (Fig. 12) an E.M.F. $B \sin pt$ be impressed upon the L branch of an oscillatory circuit connected to a thermionic tube in the usual way. It is

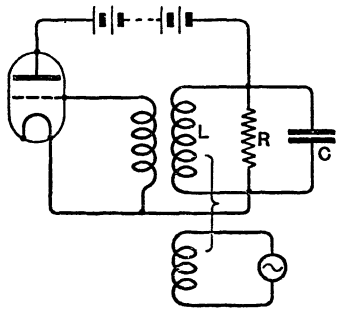

FIG. 12.

easy to show that instead of (I. [a, b]) in this case we have to solve the equations

$$\left.\begin{aligned}\frac{di}{dt}+C\frac{d^2v}{dt^2}+\frac{1}{R}\frac{dv}{dt}+\frac{1}{L}v&=\frac{B}{L}\sin pt.\\ i&=\psi(kv)\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (\text{III.})$$

If here again the derived characteristic is taken to be

$$i=-\alpha v+\beta v^2+\gamma v^3$$

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(III.) is reduced to

$$C\frac{d^2v}{dt^2}+\left(\frac{1}{R}-\alpha\right)\frac{dv}{dt}+\frac{1}{L}v+\beta\frac{d(v^2)}{dt}+\gamma\frac{d(v^3)}{dt}=B'\sin pt. \quad \text{(IV.)}$$

where $B'=\frac{B}{L}$.

A simple way of obtaining an approximate solution of (IV.), sufficiently accurate to explain some properties of the system not explained by the linear theory, is to assume v to be of the form $v=b\sin(pt+\phi)$.

We therefore only consider the case where the reaction is not sufficient to make the triode system oscillate spontaneously.

First multiply (IV.) by $\sin pt$ and integrate over the fundamental period, secondly multiply (IV.) by $\cos pt$ and integrate over the same period. We thus arrive at the two equations

$$\left(\frac{1}{Lp}-Cp\right)\cos\phi-\left\{\left(\frac{1}{R}-\alpha\right)+\frac{3}{4}\gamma b^2\right\}\sin\phi=\frac{B'}{bp}$$

$$\left(\frac{1}{Lp}-Cp\right)\sin\phi+\left\{\left(\frac{1}{R}-\alpha\right)+\frac{3}{4}\gamma b^2\right\}\cos\phi=0.$$

Eliminating ϕ results in

$$\frac{B'^2}{b^2p^2}=\left(\frac{1}{Lp}-Cp\right)^2+\left(\frac{1}{R}-\alpha+\frac{3}{4}\gamma b^2\right)^2 \quad \ldots \quad (32)$$

which gives the amplitude b of the forced vibration in terms of the constants of the circuit and the triode and of the impressed E.M.F.

Some special cases present themselves.

1. If the impressed angular frequency p is appreciably different from the natural frequency $\omega=\frac{1}{\sqrt{LC}}$, and if the impressed amplitude is small, so that the second term in the right-hand member of (32) may be neglected in comparison with the first, the simple well-known result emerges

$$b=\frac{B'}{\left(\frac{1}{L}-Cp^2\right)}$$

where the induced amplitude is simply proportional to the impressed E.M.F.

2. If the impressed E.M.F. B' is small the back coupling being adjusted such that the system is not yet oscillating $\left(\alpha<<\frac{1}{R}\right)$, $\frac{3}{4}\gamma b^2$ may be neglected in comparison with $\frac{1}{R}-\alpha$.

Then the result is

$$b^2=\frac{B'^2}{p^2}\cdot\frac{1}{\left(\frac{1}{Lp}-Cp\right)^2+\left(\frac{1}{R}-\alpha\right)^2}$$

and the circuit behaves as if the conductance $\frac{1}{R}$ parallel to the capacity were

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reduced to $\frac{1}{R} - \alpha$. If, over and above this condition, the impressed E.M.F. is in resonance with the triode circuit, we have

$$b = \frac{B'}{p} \cdot \frac{1}{\frac{1}{R} - \alpha}$$

showing that, with a retro-action such that

$$\alpha = \left(g\frac{M}{L} - 1\right) \cdot \frac{di_a}{dv_a} < 0$$

the system presents a damping greater than would occur without the triode, while for

$$\alpha > 0$$

the damping is reduced, resulting in a greater amplitude than would be obtained without the triode. Hence the resistance term $\frac{1}{R}$ is simply reduced or increased to $\frac{1}{R} - \alpha$.

With the retro-action adjusted such that exactly $g\frac{M}{L} - 1 = 0$ the system has, with the triode, the same damping as without. This affords an easy means of obtaining the voltage magnification factor g under actual (high frequency) working conditions. The experiment therefore consists in letting (*e.g.* by means of a second oscillating triode system) an E.M.F. be induced in the inductance of the triode system under consideration. Next measure (*e.g.* with crystal and galvanometer) the current induced when the heating current is cut off. Now heat the filament and adjust the back coupling until the same galvanometer deflection is obtained, then

$$g = \frac{M}{L}.$$

Obviously this method is independent of any calibration of the galvanometer-crystal combination.

3. If, finally, under resonance condition, the retro-action is adjusted near the point where the system would just commence to oscillate freely, and therefore

$$\alpha \doteq \frac{1}{R}$$

we have

$$\frac{B'}{p} = \frac{3}{4}\gamma b^3$$

or

$$b = \sqrt[3]{\frac{B'}{\frac{3}{4}\gamma p}} \quad \ldots\ldots\ldots \quad (33)$$

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The same formula (33) may also be applied if, in general, the induced E.M.F. is big enough to make the resulting induced b such that

$$\frac{3}{4}\gamma b^2 >> \frac{1}{R} - \alpha$$

and

$$\frac{3}{4}\gamma b^2 >> \frac{1}{pL} - Cp$$

thus showing clearly the well-known limiting action of a triode. For, under these conditions, the resulting amplitude, instead of being proportional to the *first power* of the induced E.M.F., is proportional to the *third power root* of the same quantity. Small oscillations are therefore magnified to a greater extent than bigger ones.

4. In conclusion the main results of Parts I. and II. of this paper may be summarised as follows:

An oscillatory circuit consisting of three parallel branches L, C and R, and connected in the usual way to a triode generator behaves as if the conductance $\frac{1}{R}$ were reduced to

$$\frac{1}{R} - \alpha + \frac{3}{4}\gamma a^2$$

where a is the alternating voltage across the plate-filament.

For self-oscillation this conductance must be zero, thus yielding at once the amplitude of the vibrations in terms of the circuit and triode constants.

If an impressed E.M.F. is applied to the system, the conductance is reduced to the same value, while a again represents the alternating P.D. set up between plate and filament.

As long, therefore, as only *one single* vibration is present in any system of triodes and circuits, however complicated it may be, the simple well-known alternating current theory may be used to find the resulting amplitudes in the different circuits, in terms of the triode constants α and γ if only the conductance $\frac{1}{R}$ be replaced by $\frac{1}{R} - \alpha + \frac{3}{4}\gamma a^2$.

Finally, the parallel conductance $\frac{1}{R}$, which materially simplifies the formulæ, can easily be replaced by a series resistance, either in the L or C branch, as indicated in the paper.

Physical Laboratory,
Teyler's Institute, Haarlem (Holland).

July 17th, 1920.

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The Calculation of the Self and Mutual Inductance of Coils.

At intervals during the past year A. Esau has published papers dealing with the calculation of the inductance of coils of various types, and although abstracts have been given these have been too brief to enable one to use Esau's results without reference to the original publications. We have been asked therefore to give further information as to the values of the various coefficients appearing in the final formulæ, so that these may be used without reference to the original papers.

I. Single layer coil on square frame.*

L = inductance in cm; a = side of square; n = number of turns; g = pitch of turns; ρ = radius of wire.

$$\text{then } L = 8\,an(S_1 + S_2)$$

where $S_1 = f\left(\frac{a}{\rho}\right)$ and $S_2 = f\left(\frac{g}{a}, n\right)$.

Table I. gives the values of $S_1 = f\left(\frac{a}{\rho}\right)$ and Table II. the values of $S_2 = f\left(\frac{g}{a}, n\right)$.

TABLE I.

a/ρ	S_1	a/ρ	S_1
20	2·472	300	5·180
30	2·877	400	5·467
40	3·165	500	5·691
50	3·388	600	5·873
60	3·570	700	6·027
70	3·724	800	6·161
80	3·858	900	6·278
90	3·976	1000	6·383
100	4·081	2000	7·077
120	4·264	3000	7·483
140	4·418	4000	7·770
160	4·551	5000	7·993
180	4·669	10000	8·690
200	4·774		

* RADIO REVIEW Abstract No. 73, December, 1919.

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TABLE II.

n	Values of g/a.							
	0·002	0·004	0·006	0·008	0·01	0·02	0·03	0·04
2	5·44	4·75	4·36	4·06	3·84	3·16	2·76	2·49
3	10·43	9·04	8·26	7·67	7·23	5·87	5·08	4·55
4	15·09	13·02	11·84	10·96	10·30	8·27	7·10	6·31
5	19·52	16·75	15·19	14·02	13·14	10·45	8·90	7·86
6	23·75	20·32	18·34	16·88	15·79	12·44	10·52	9·24
7	27·81	23·69	21·33	19·59	18·27	14·28	11·99	10·47
8	31·74	26·94	24·19	22·16	20·63	16·00	13·35	11·60
9	35·55	30·67	26·92	24·60	22·87	17·59	14·60	12·63
10	39·24	33·09	29·56	26·96	25·01	19·11	15·77	13·58
11	42·84	36·01	32·09	29·21	27·05	20·53	16·85	14·45
12	46·36	38·86	34·56	31·39	29·02	21·89	17·88	15·26
13	49·77	41·60	36·92	33·43	30·90	23·18	18·82	16·00
14	53·12	44·28	39·21	35·44	32·71	24·39	19·71	16·69
15	56·40	46·89	41·44	37·39	34·46	25·54	20·55	17·33
16	59·62	49·44	43·61	39·28	36·15	26·65	21·33	17·89
17	62·78	51·93	45·73	41·12	37·79	27·71	22·08	18·45
18	65·88	54·36	47·78	42·89	39·37	28·71	22·78	18·97
19	68·92	56·74	49·78	44·62	40·90	29·68	23·46	19·44
20	71·92	59·07	51·74	46·30	42·39	30·61	24·10	19·89
21	74·86	61·36	53·65	47·94	43·84	31·50	24·71	20·32
22	77·76	63·59	55·52	49·54	45·24	32·36	25·23	20·70
23	80·63	65·80	57·33	51·11	46·62	33·20	25·91	21·07
24	83·38	67·92	59·15	52·58	47·91	33·95	26·37	21·37
25	86·21	70·03	60·85	54·06	49·20	34·72	26·80	21·66

II. Square plane or pancake coils.*

$$L = 8\,an(S_1 + S_3)$$

where $S_1 = f\left(\frac{a}{\rho}\right)$ is the same as in the previous case (Table I.) and $S_3 = f\left(\frac{g}{a}, n\right)$. Table III. gives the values of S_3.

a is here the side of the mean turn.

* RADIO REVIEW Abstract No. 272, April, 1920.

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TABLE III.

n	Values of g/a.				
	0·002	0·004	0·01	0·02	0·04
2	5·44	4·76	3·90	3·18	2·49
3	10·43	9·05	7·21	5·85	4·49
4	15·09	13·02	10·23	8·24	6·23
5	19·50	16·76	13·10	10·38	7·71
6	23·74	20·29	15·73	12·35	9·06
7	27·79	25·63	18·20	14·15	10·26
8	31·71	26·91	20·54	16·83	11·34
9	35·51	30·02	22·75	17·39	12·31
10	39·20	33·04	24·88	18·90	13·19
11	42·79	35·94	26·89	20·26	13·99
12	46·30	38·78	28·83	21·58	14·76
13	49·72	41·51	30·68	22·79	15·46
14	53·06	44·17	32·45	23·95	16·10
15	56·32	46·76	34·17	25·08	16·78
16	59·54	49·30	35·85	26·15	17·42
17	62·69	51·67	37·43	27·11	17·89
18	65·76	54·18	39·02	28·10	18·33
19	68·80	56·54	40·49	29·02	19·03
20	71·78	58·87	41·93	29·89	19·39
21	74·72	61·12	43·32	30·70	19·95
22	77·60	63·34	44·65	31·50	20·44
23	80·46	65·53	46·06	32·32	20·97
24	83·22	67·62	47·26	33·03	21·44
25	85·96	69·71	48·51	33·73	21·91

III. Multi-layer coils.*

$$L = 4\pi rmn(S_4 + S_5)$$

where r = mean radius of coil.

m = number of layers.

n = number of turns per layer.

ρ = radius of wire.

$S_4 = f\left(\frac{r}{\rho}\right)$ (see Table IV.),

* See RADIO REVIEW Abstract No. 329, May, 1920.

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and $S_5 = f\left(\frac{g}{2r}, n, m\right)$ (see Tables VA. and VB.).

g = pitch of turns in a layer, which is assumed to be equal to the radial pitch of successive layers.

Table VA. gives the values of S_5 for $m = 2$ and Table VB. the values for $m = 3$.

TABLE IV.

r/ρ	S_4	r/ρ	S_4	r/ρ	S_4
20	3·329	120	5·121	700	6·884
30	3·734	140	5·275	800	7·018
40	4·022	160	5·408	900	7·135
50	4·245	180	5·526	1000	7·240
60	4·427	200	5·631	2000	7·934
70	4·581	300	6·037	5000	8·850
80	4·715	400	6·324	10000	9·543
90	4·833	500	6·548		
100	4·938	600	6·730		

TABLE VA. $m = 2$.

n	Values of $g/2r$.			
	0·002	0·004	0·01	0·02
2	16·45	14·37	11·62	9·55
3	26·54	23·08	18·49	15·04
4	36·07	31·22	24·80	20·00
5	45·13	38·89	30·64	24·48
6	53·84	46·22	36·15	28·61
7	62·24	53·26	41·33	32·36
8	70·34	60·00	46·25	36·04
9	78·26	66·47	50·90	39·34
10	85·88	72·74	55·36	42·49
11	93·35	78·84	59·64	45·44
12	99·80	83·94	63·93	47·42
13	107·8	90·54	67·72	50·93
14	114·7	96·15	71·52	53·45
15	121·6	101·6	75·21	55·88

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TABLE Vb. $m = 3$.

n	Values of $g/2r$.			
	0·002	0·004	0·01	0·02
2	26·54	23·09	18·49	15·05
3	41·36	35·84	28·48	22·98
4	55·44	47·85	37·75	30·17
5	68·89	59·23	46·40	36·74
6	81·80	70·07	54·48	42·85
7	94·30	80·50	62·17	48·50
8	106·4	90·56	69·49	53·84
9	118·2	100·2	76·42	58·78
10	129·6	109·6	83·05	63·43
11	140·8	118·7	89·46	67·89
12	150·6	126·4	94·46	70·96
13	162·3	136·1	101·4	74·96
14	172·7	144·5	107·1	79·60
15	182·9	152·6	112·5	83·20

TABLE VI.

n	Values of $g/2r$.			
	0·002	0·004	0·01	0·02
2	16·45	14·38	11·62	9·56
3	41·36	35·84	28·48	22·98
4	73·90	63·55	49·75	39·48
5	113·52	96·90	74·90	58·48
6	159·7	135·6	103·5	79·58
7	212·2	179·1	135·0	102·5
8	270·5	227·0	169·2	126·7
9	334·6	279·4	206·3	152·4
10	405·9	337·6	247·3	181·0
11	478·4	395·7	286·3	206·3
12	558·2	459·5	329·4	234·5
13	643·0	527·0	374·0	264·0
14	734·0	600·0	423·0	295·0
15	825·0	671·0	468·0	322·0

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If the winding space is square $m = n$ and

$$L = 4\pi r n^2 (S_4 + S_6)$$

where n = turns per layer = number of layers

n^2 = total number of turns

and $S_6 = f\left(\frac{g}{2r}, n^2\right)$—see Table VI.

IV. Attention should also be drawn to Abstract No. **1192** on p. 773 of this issue, where formulæ and tables are given for the self and mutual inductances of single square turns.

G. W. O. H.

Mica Condensers for Radio Work.

By PHILIP R. COURSEY, B.Sc.

The use of mica as a dielectric for condensers for high voltage work has increased greatly in the past few years. In particular the commercial development of these types of condensers has been carried on by the Dubilier Condenser Company, Inc., of New York, by the Wireless Speciality Apparatus Company also of New York, and by the Dubilier Condenser Company of London. Condensers manufactured by these firms have been used extensively during the war for radio work by many of the Allied Governments as well as by commercial wireless companies.

In a recent infringement suit brought by the Dubilier Condenser Company, Inc., against the Wireless Speciality Apparatus Company (who manufacture condensers under the trade name of "Faradon") a final decree has been handed down by His Honour Augustus N. Hand, U.S. District Judge for the Southern District of New York, on October 4th, 1920, holding :—

"That said Letters Patent Nos. 1,229,914 and 1,229,915 are good and valid in law as to the second, third, fourth, fifth, seventh, eighth, ninth, twelfth, fourteenth, and fifteenth claims of Letters Patent No. 1,229,914 and as to the first, eighth, twelfth, sixteenth and seventeenth claims of Letters Patent No. 1,229,915.

That the defendant Wireless Speciality Apparatus Company has infringed upon each and all of said claims, of said Letters Patent Nos. 1,229,914, and 1,229,915 by manufacturing, selling and using, or causing to be manufactured, sold or used, condensers embodying or employing the inventions of said claims of said Letters Patent.

That the fourth claim of Letters Patent No. 1,229,915 is invalid in law, being anticipated by the prior use of the subject-matter thereof by the United States Navy, and National Electrical Supply Company of Washington, D.C., and that the bill be dismissed as to said claim of said patent."

The patents in question deal respectively with means for boxing up the complete condenser in a metallic case, and for the method of constructing high voltage condensers. The claims referred to in the judgment cover in effect the following leading features :—A condenser so constructed that one

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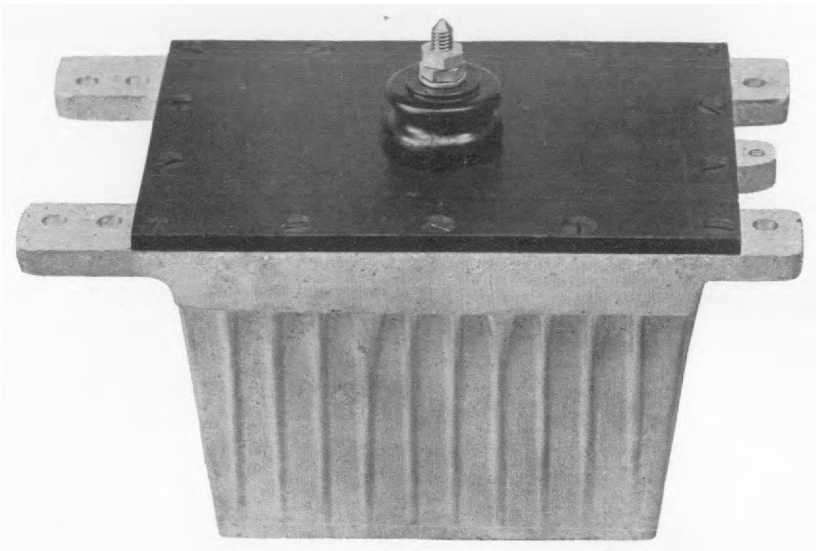

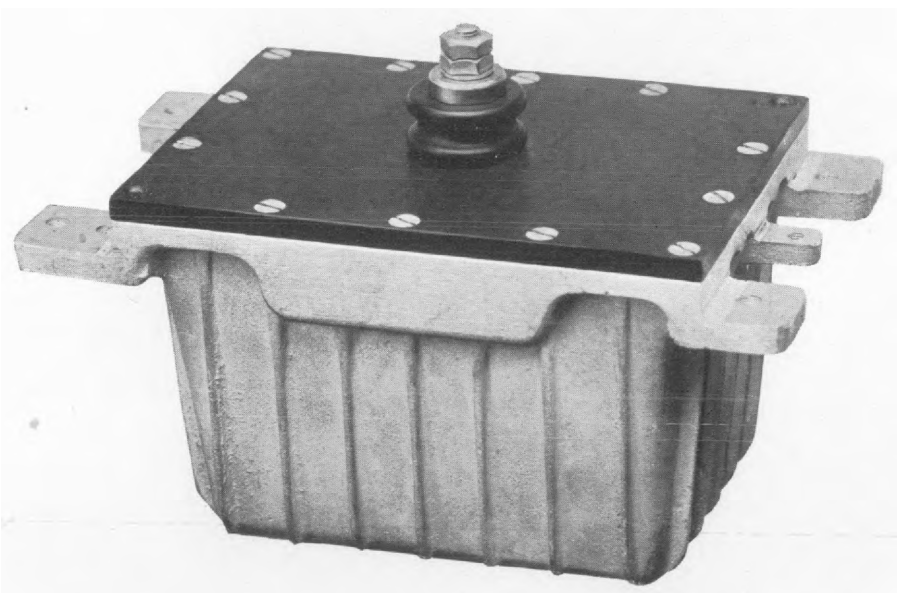

FIG. 1.—OUTSIDE VIEW OF TWO PATTERNS OF DUBILIER MICA CONDENSER, SHOWING METALLIC CASE WITH INCLINED SIDES AND INSULATED TERMINAL IN LID.

(*To face p.* 768.)

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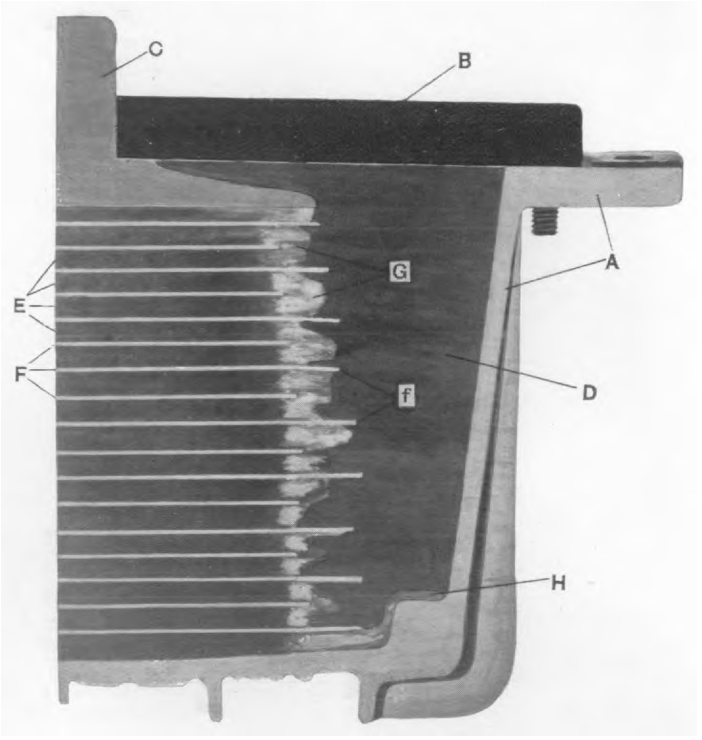

FIG. 2.—CROSS SECTIONAL VIEW OF MICA CONDENSER IN CONTAINING CASE SAWN THROUGH CENTRALLY.

A = Metal case with inclined sides. B = Insulating lid. C = Terminal in lid provided with enlarged lower surface for compressing the condenser. D = Insulating filling compound. E = Condenser sections which are connected in series to form the complete unit. F = Mica insulating barriers. G = Soldered connections between condenser sections. H = Connection between lowest section and case.

(*To face p.* 769.)

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of its terminals is formed by the metallic containing case while the other is arranged so as to compress the condenser into the case. These terminals should preferably be of relatively small mass and relatively large surface to enable them to conduct away any heat from the interior of the condenser case. The second terminal may be mounted in or through an insulating lid or closure for the containing case, and it is then enabled to serve not only as an electrical connection to the condenser but also for compressing the condenser and preventing its expansion or vibration when in use, as well as for conducting away the heat.

In order to provide greater insulation from the case at the high potential end of the condenser—*i.e.*, the end connected to the insulated terminal in the lid—the use of a case having inclined sides is covered by the claims that have been upheld. The condenser unit is disposed centrally within the casing with its elements parallel to the bottom, the sides of the case sloping outwards so as to obtain a greater spacing between the condenser sections and the case at the upper end of the unit.

As regards the construction of mica condensers for high voltage circuits, the claims of U.S. Patent 1,229,915 which have been upheld cover a high tension condenser unit consisting of sections connected in series for dividing the potential among them, each section comprising conducting plates and intervening sheets of insulation constituting the dielectric, the said sheets having a layer of insulating adhesive between them and the conductor plates and being arranged to overlap the edges of the conductor plates. Between adjacent sections extra insulating plates are customarily inserted so as to have their ends projecting alternately in opposite directions beyond the condenser sections so that the terminals of the sections can be joined together in pairs between the projecting ends of the insulating plates. This last feature of construction is one, however, that has not been upheld in the infringement suit on account of prior use. The fourth claim of Patent 1,229,915 which has been held to be invalid for this reason reads as follows :—

"A condenser unit comprising sections, and insulating plates between the sections, said plates being arranged to have their end projecting alternately in opposite directions, whereby the terminals of the sections can be joined together in pairs at both ends of said plates, the projecting ends of the plates intervening between the sections having their terminals so connected and adjacent sections."

In order to render clearer the features of this type of condenser construction the general appearance of two condensers built in accordance with these specifications is shown in Fig. 1, while in Fig. 2 is an interesting illustration of a condenser which has been sawn through centrally, perpendicularly to the condenser plates, in order to show the internal arrangements. The reference letters placed on this illustration indicate the parts mentioned above. The insulating barriers between the condenser sections, each of which consists of a complete small condenser comprising interleaved sheets of mica and metal foil, may be seen at F, the alternately projecting ends, which separate the soldered connections G between condenser sections, being indicated at f.

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Features for the New Volume.

By THE EDITOR.

With this issue we complete the first volume of the RADIO REVIEW. In order to avoid the disadvantage which one always experiences when looking up references to a journal in which the change of volume does not coincide with the change of year, it was decided not to close the first volume with the twelfth monthly issue in September, but to run on to the end of the year.

The experience gained during the last fifteen months has suggested a number of improvements which it is intended to introduce in the new volume. Some of these improvements are due to suggestions made by readers, and we take this opportunity of thanking them for writing to point out ways in which they considered that the usefulness and interest of the RADIO REVIEW might be increased. By using a thinner paper it will be possible to increase the number of pages in each issue without increasing the bulk of the annual volume. By increasing the number of pages it will be possible to publish more papers of general interest as distinct from those which, by reason of their mathematical character or of their detailed investigation of specific points, appeal to a smaller circle of readers. It is also intended to publish translations either in full or abbreviated of those articles in foreign periodicals which appear to be of such importance as to merit fuller treatment than is possible in a brief abstract. An abstract can only indicate the general nature of an article, but cannot in many cases give sufficient detail for a person specially interested in that branch of the subject. If the original article is in a language with which the reader is familiar, he can then refer to it for further detail, and the abstract has fulfilled its purpose. In many cases, however, this will not be so, and we have therefore decided to devote considerable space to translations of foreign papers which are likely to interest the majority of our readers.

A new feature will be the inclusion of personal, scientific, and commercial notes relating to radiotelegraphy. A section will be devoted to the wireless telegraphy laws of various countries so that all changes in the legislation affecting radio work will be noted in our columns.

In order to increase their utility the abstracts of articles, patents, etc., will be classified so that it will be possible to refer without any trouble to the information recently published about any particular branch of the subject. As part of this classification references will be included to those articles which are dealt with more fully in other parts of the REVIEW, so that the references under any given subject heading will be quite complete.

By thus broadening the scope of the RADIO REVIEW it is hoped to make it of greater value to all wireless engineers and students of radiotelegraphy and telephony as well as to the scientist and research worker.

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Review of Radio Literature.

1. Articles and Patents.

1182. ELECTROSTATICALLY COUPLED CIRCUITS. L. Cohen. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 434—437, October, 1920.)

The theory of electrostatic coupling is discussed from the point of view of energy transfer and sharpness of tuning. The circuit considered is shown in Fig. 1, where C_1 L_1 and C_2 L_2 are the two oscillatory circuits and C_0 the coupling condenser. In the case of syntony (when $C_1 L_1 = C_2 L_2$) there are two natural frequencies of oscillation f_1 and f_2 where

$$f_1 = \frac{1}{2\pi\sqrt{LC}}$$

$$f_2 = \frac{1}{2\pi\sqrt{LC\left(1+\frac{C_0}{C_1}+\frac{C_0}{C_2}\right)}}$$

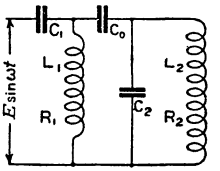

FIG. 1.

It is shown that even for tight coupling to get the maximum energy transfer to the secondary circuits C_0 is small in comparison with C_1 and C_2 so that for practical purposes the assembly has one frequency. The current in the secondary circuit L_2C_2 is shown to be

$$\frac{E}{\sqrt{\left(R_1R_2\frac{C_1C_2\omega}{C_0}\right)^2+\left(R_2\frac{C_2}{C_1}\right)^2}}$$

In a comparison with electromagnetic coupling it is shown that the secondary resonance currents in the two cases are of the same order of magnitude but that the electrostatic coupling yields superior sharpness of resonance.

1183. THE ADJUSTMENT OF COUPLING IN QUENCHED SPARK SYSTEMS. (*Elektrotechnische Zeitschrift*, 41, p. 556, July 15th, 1920.)

The German courts have decided in favour of the Telefunken Company's Patent No. 198562 for the use of the critical value of the coupling to give the optimum effect, and have forbidden E. Huth & Co. to use a system in which the coupling is so adjustable.

1184. THE ENERGY RELATIONS IN A CIRCUIT WITH SELF-INDUCTION. P. Terpstra. (*Physikalische Zeitschrift*, 21, pp. 467—469, September 1st, 1920.)

Shows how the energy stored in the field and that lost as heat when a steady P.D. is suddenly applied to an inductive circuit can be represented graphically by the volumes enclosed by certain curved surfaces.

1185. A MECHANICAL APPARATUS FOR DEMONSTRATING PROPERTIES OF OSCILLATORY CIRCUITS. O. Oldenberg. (*Physikalische Zeitschrift*, 21, pp. 463—465, September 1st, 1920.)

A system of coupled pendulums with electromagnetic damping, fitted with projecting and recording devices. The system is analogous to electric circuits with capacity coupling. All the various quantities can be readily varied. It was designed by Simon and is now being made by Leybolds of Cologne.

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1186. ELECTRICAL OSCILLATIONS IN ANTENNAS AND INDUCTION COILS. A. Hund. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 424—430, October, 1920.)

Further discussion of the paper by J. M. Miller with the above title.* The calculation of the correct effective antenna constants is dealt with for any case of coil loading for a long horizontal antenna excited by a sinusoidal radio frequency electromotive force. If C and L are the correct antenna capacity and inductance we have

$$C = \frac{8\lambda'}{\pi\lambda} \frac{\sin^2 90 \frac{\lambda}{\lambda'}}{\pi \frac{\lambda}{\lambda'} + \sin 180 \left(1 - \frac{\lambda}{\lambda'}\right)} C_A$$

$$L = \frac{\lambda'}{2\pi\lambda} \frac{\pi \frac{\lambda}{\lambda'} - \sin 180 \left(1 - \frac{\lambda}{\lambda'}\right)}{\sin^2 90 \frac{\lambda}{\lambda'}} . L_A$$

where λ and λ' denote the natural fundamental wavelengths for the unloaded and the coil-loaded antenna system respectively. The quantities C_A and L_A represent the static antenna constants for which the potential as well as the current are for all points of the horizontal length of antenna of unchanged amplitude and same phase. C_A and L_A may be determined by any of the ordinary low frequency methods.

1187. THE USE OF GROUND WIRES AT REMOTE CONTROL STATIONS. E. W. Stone. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 431—433, October, 1920.)

Further discussion of the paper with the above title by A. H. Taylor and A. Crossley, previously published.†

Experiments with ground and water wires (similar to those of Taylor's) were carried out at North Island with very successful results. Taylor accounts for the operation of the buried antennæ by the induction of potentials within the wire by the horizontal component of the tilted electromagnetic wave front. This explanation however does not account for the action of submarine antennæ in which case the most satisfactory operation is always obtained with a medium of good conductivity. To explain this the theory is suggested that the potentials are induced in the antenna wire by the magnetic field surrounding the currents produced in the earth or water. Since these earth currents are greatest in media of high conductivity there will be maximum induction of potentials with consequent greatest signal strength.

1188. THE WAVELENGTH RELATION FOR A GENERALISED BESSEL'S ANTENNA. A. Press. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 441—447, October, 1920.)

A continuation of the author's discussion ‡ of a vertical antenna taking into account the variable distribution of both inductance and capacity per unit length of the aerial. An antenna of negligible resistance and height l is assumed together with an impressed frequency f such that $\frac{\pi l}{\lambda} = 1$ where λ is the wavelength corresponding to f. The solution for the voltage and current distribution along the antenna is given in terms of Bessel's Functions. Curves for ready application to numerical cases are given.

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* See RADIO REVIEW Abstract No. 2, October, 1919, for abstract of the original paper; also No. 269, April, 1920, for further reference to additional discussion.

† See RADIO REVIEW Abstract No. 832, September, 1920, for abstract of the original paper.

‡ See *Proceedings of the Institute of Radio Engineers*, December, 1918.

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1189. THE EFFICIENCY OF AERIALS, AND THE POWER REQUIRED FOR LONG DISTANCE TRANSMISSION. G. W. O. Howe. (*Electrician*, 85, pp. 298—300, September 10th, 1920. *Technical Review*, 7, pp. 144—145, November 2nd, 1920 —Abstract.)

Paper read before Section G of the British Association at Cardiff. The subject-matter is covered by the editorial articles in our August and September issues,* where the full paper was given with all the diagrams.

1190. OSCILLATING CIRCUITS WITH TRIODE GENERATORS AS ACOUSTIC FREQUENCY STANDARDS. (*Zeitschrift für Instrumentenkunde*, 40, pp. 119—120, June, 1920.)

The Reichsanstalt has made experiments to see whether the constancy of the frequency is such that such valve circuits could be used instead of standard tuning forks. The possibility of a continuous variation of the frequency would be a great advantage. Experiments showed that with proper precautions the frequency was constant to 1 part in 10,000 even when the triode was changed.

1191. A SIMPLE METHOD OF CALCULATING THE INDUCTANCE OF A SINGLE LAYER WINDING. (*La T.S.F. Moderne*, 1, pp. 151—154, August, 1920.)

The method first described is essentially that first developed by H. Nagaoka. (Inaccuracies in the formulæ and numerical examples were corrected in the September issue.)

1192. THE MUTUAL INDUCTANCE OF SINGLE TURN RECTANGLES AND SQUARES. A. Esau. (*Annalen der Physik*, 61, pp. 410—420, February 22nd, 1920. *Science Abstracts*, 23A, pp. 289—290, Abstract No. 743, May 31st, 1920—Abstract.)†

The author develops a formula for the mutual inductance of two parallel rectangles of different sizes but symmetrically placed and then considers several special cases, obtaining results in accordance with the known formulæ for these cases. Simplified approximate formulæ are obtained for the case of squares of nearly the same size, when separated by a short distance. The accurate formula for the mutual inductance of two squares placed parallel and symmetrical is simplified and written thus

$$M = aS$$

where a = side of smaller square
$a + 2c$ = side of large square
d = distance between the planes of the squares
$S = f(c/a, d/a)$, the values of which are given in the following table.

c/a	Values of d/a						
	0·0	0·1	0·2	0·5	1·0	2·0	4·0
0·0	—	13·02	8·264	3·224	1·016	0·202	0·028
0·1	14·74	12·12	8·832	3·688	1·312	0·264	0·036
0·2	10·70	9·904	8·232	4·232	1·576	0·360	0·056
0·5	6·40	6·256	5·872	4·264	2·136	0·600	0·112
1·0	3·968	3·936	3·856	3·384	2·328	0·952	0·208
2·0	2·320	2·296	2·256	2·176	1·888	1·184	0·416
4·0	1·232	1·248	1·256	1·232	1·200	1·200	0·568

* RADIO REVIEW, 1, pp. 540—543, August, and pp. 598—608, September, 1920.
† See also pp. 763—768, in this issue.

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This formula in conjunction with the following formula for the self-inductance of a single square turn enables one to calculate the coupling coefficient of two single square turns.

$$L = aS', \text{ where } S' = f\left(\frac{a}{\rho}\right) \text{ and } \rho = \text{radius of wire.}$$

a/ρ	S'	a/ρ	S'	a/ρ	S'
20	20·18	200	38·23	2000	56·62
40	25·52	400	43·76	4000	62·16
60	27·90	600	47·00	6000	65·41
80	30·97	800	49·30	8000	67·70
100	32·73	1000	51·08	10000	69·49

1193. A METHOD FOR MEASURING FREQUENCIES. A. Zacek. (*Physikalische Zeitschrift*, 20, pp. 348—350, August 1st, 1919. *Electrical World*, 75, p. 1150, May 15th, 1920—Abstract.)

An apparatus is referred to comprising a double branch test circuit each one branch containing an ohmic resistance and the other an inductance. The heater wire of a thermo-element is included in each branch, and the thermocouples themselves connected to the two windings of a differential galvanometer. The frequency of the test current may be determined by varying the resistance branch until the galvanometer shows zero deflection.

1194. THE USE OF THE TELEPHONE RECEIVER IN BRIDGE METHODS. (*Zeitschrift für Instrumentenkunde*, 40, pp. 123—124, June, 1920.)

Low-frequency A.C. can be used if a buzzer be inserted to interrupt the current. The arrangement is inferior to the vibration galvanometer.

1195. THE INTENSITY OF WIRELESS SIGNALS. (*Scientific American*, 123, p. 149, August 14th, 1920.)

Reference is made to a method of comparing the strengths of received radio signals which has been worked out in France. It is applicable only to C.W. reception and the comparison is made by adjusting a local source of oscillations to give the same heterodyne note and signal strength as that of the incoming signals. Fine adjustment can be obtained by shunting the telephones. An accuracy of between 5 and 10 per cent. is claimed.

1196. MEASUREMENT OF SMALL MUTUAL INDUCTANCE. (*Zeitschrift für Instrumentenkunde*, 40, pp. 122—123, June, 1920.)

The coil L_1, Fig. 2, constitutes the primary of the mutual inductance M. r is a fixed and R an adjustable resistance. If R is kept negligibly small compared with $1/\omega C$, zero reading is obtained on the galvanometer G when $M = CrR$. It is important to make an earth connection at the indicated point. The method is only suitable when M is small.

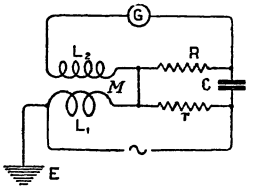

FIG. 2.

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1197. THE PRODUCTION OF VERY SHORT WAVES BY MEANS OF TRIODES. R. Ettenreich. (*Verhandlungen der Deutschen Physikalischen Gesellschaft*, 1, pp. 49—50, June 10th, 1920.)

A brief summary of an experimental lecture given at Vienna illustrating the phenomenon discovered by Barkhausen (see RADIO REVIEW, 1, p. 434, June, 1920).

1198. THE CATHODE RAY OSCILLOGRAPH. (*Scientific American*, 123, p. 121, August 7th, 1920.)

A short note referring to the utility of the cathode ray oscillograph for radio frequency work.

1199. THE CORONA VOLTMETER AND THE ELECTRIC STRENGTH OF AIR. J. B. Whitehead and T. Isshiki. (*Journal of the American Institute of Electrical Engineers*, 39, pp. 441—444, and pp. 511—526, May, 1920. *Science Abstracts*, 23B, pp. 339—340, Abstract No. 661, July 31st, 1920—Abstract. *Technical Review*, 7, pp. 64—65, October 19th, 1920—Abstract.)

Discusses the possibilities of utilising the phenomena of the corona discharge for the measurement of high voltages.

1200. CALIBRATION OF WAVEMETERS. (*Zeitschrift für Instrumentenkunde*, 40, pp. 120—121, June, 1920.)

An account of the determination of the frequencies of standard wavemeters at the Reichsanstalt. Harmonics are used for the higher frequencies and the frequency of the fundamental was determined (1) by measuring the inductance and capacity, (2) by acoustic methods and (3) by measuring the speed of a high-frequency alternator. In the case of a circuit of 0·02 μF and 0·01 H the three methods gave 10,567, 10,570 and 10,573 cycles per second.

1201. TRANSMITTER FOR USE ON DIRECT CURRENT. (*Wireless Age*, 7, p. 22, September, 1920.)

A description is given of a motor-driven commutator arrangement—here termed a resonant converter—for transforming direct current into low-frequency alternating current for wireless transmission. A rotary spark gap is mounted on the same shaft as the commutator and the arrangement of connections of the direct current supply follows the usual one for such apparatus. The low-frequency circuit through the commutator is tuned to the frequency of interruption.

1202. APPARATUS FOR GENERATING OSCILLATIONS. E. F. Huth and S. Loewe. (*German Patent* 307712, March 14th, 1917. Patent granted October 7th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 488, June, 1920.)

An arrangement in which quenched spark gaps QQ are connected in series with rectifying devices RR. Both half cycles of the A.C. source are thus used. See Fig. 3.

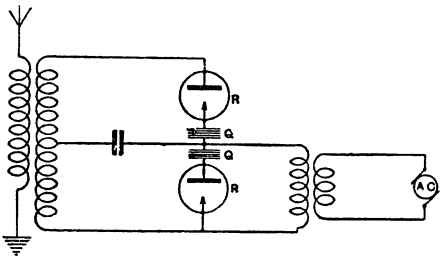

FIG. 3.

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1203. METHOD OF SIGNALLING WITH AN ARC. (*Wireless Age*, 7, p. 23, January, 1920.)

Abstract of a patent by R. G. Marks and L. F. Fuller describing a means whereby the oscillations set up by an arc oscillation generator may be started and stopped by means of the ordinary telegraphic key. When the key is depressed the arc is shunted by an electrolytic lightning arrester of three or four units, the discharge through which suppresses the arc. On releasing the key the circuit through this arrester is broken and a high-voltage high-frequency source is momentarily switched on to create a potential difference across the arc terminals sufficient to reignite the arc. The arc may thus be extinguished and relighted at ordinary telegraphic speed.

1204. THE 10 kW VACUUM TUBE TRANSMITTER OF THE TELEFUNKEN COMPANY. W. Schäffer. (*Telefunken Zeitung*, 4, No. 21, pp. 20—26, July, 1920.)

A description with photographs and diagrams of connections of a transmitter containing thirty tubes in parallel supplied at 3,000 volts and supplying 10 kW to the direct coupled aerial.

1205. VOLTAGE SOURCE FOR VALVE TRANSMITTERS. C. Lorenz. (*German Patent* 310121, July 24th, 1918. Patent granted October 4th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, p. 165, February, 1920—Abstract.)

A series arrangement of an alternating current source and a direct current source by means of which either type of voltage may be used as required.

1206. CONTRIBUTION TO THE THEORY OF AUDION GENERATORS: THE CONDITION FOR EXCITATION AND THE DEGREE OF DAMPING OF FEEBLE OSCILLATIONS OBTAINED FROM THIS APPARATUS. A. Blondel and C. Lavonchy. (*Science Abstracts*, 23B, p. 112, Abstract No. 215, February, 1920—Abstract.)

See RADIO REVIEW Abstract No. 419, June, 1920.

1207. A GRAPHICAL STUDY OF THE OPERATION OF AUDIONS AS SENSITIVE RECEIVERS OR AS DECREMENT PRODUCERS ("DESAMORTISSEURS") IN A RESONANT CIRCUIT. A. Blondel. (*Science Abstracts*, 23A, p. 240, Abstract No. 611, April, 1920—Abstract.)

See RADIO REVIEW Abstract No. 422, June, 1920.

1208. HIGH-FREQUENCY ALTERNATOR. Société Française Radio-Électrique. (*French Patent* 487996, March 13th, 1915. Published August 9th, 1918.)

To obtain a constant load on the shaft of a high-frequency alternator used in wireless telegraphy, so as to maintain a constant frequency, an auxiliary generator is mechanically coupled to the alternator. The auxiliary generator is excited and acts as a load when the alternator is not excited. In the apparatus described the auxiliary generator is a three-phase alternator and it has a de-magnetising winding connected to the exciter for the high-frequency alternator, in such a manner that the said winding and the exciting winding of the high-frequency alternator are controlled by the signalling switch. For further particulars see British Patent 100184.

1209. TRANSOCEANIC RADIO COMMUNICATION. E. F. W. Alexanderson. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 263—285, August, 1920.)

This paper was presented at a joint meeting of the American Institute of Electrical Engineers and the Institute of Radio Engineers and the report of it in the *Proceedings of the American Institute of Electrical Engineers* has already been abstracted.* In this account photographs

* RADIO REVIEW Abstract No. 216, March, 1920.

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of the installation at New Brunswick, N.J., are given together with a detailed description from which the following details are taken.

The generator in use at present is a 200 kW radio frequency alternator which when operated at a wavelength of 13,000 metres runs at a speed of 2,170 r.p.m. As the wavelength depends on the speed an important accessory is the speed regulator, the speed determining element of which is a resonant radio frequency circuit fed by one of the sixty-four alternator windings and which is set aside for that purpose.

The method of modulating or controlling the radio frequency energy for telegraphy involves the use of the magnetic amplifier, while when the station is used for telephony the controlling current is an amplified telephone current. The antenna is of the multiple type with a total resistance of 0·5 ohm.

1210. WIRELESS TELEPHONY AT THE TELEFUNKEN EXHIBITION. (*Telefunken Zeitung*, 4, No. 21, pp. 60—62, July, 1920.)

A description of a set permanently installed for demonstration; it works with another station across a canal.

1211. CONDENSER TYPE TRANSMITTER. I. B. Crandall. (*Electrical World*, 75, p. 1151, May 15th, 1920.)

Some measurements are referred to on the sensitiveness and other constants of a telephone transmitter of the condenser type.

1212. A NEW MICROPHONE. A. Soret and R. Couespel. (*Annales des Postes, Télégraphes et Téléphones*, 8, p. 666, December, 1919. *Telegraphen- und Fernsprech-Technik*, p. 33, May, 1920—Abstract.)

In this microphone the granules are not in contact with one another but only with the carbon block and the diaphragm; the former is 27 mm. diameter and contains 220 cavities each with a single granule; the diaphragm is only 0·2 mm. thick and is highly polished, the best adjustment is obtained by means of a micrometer screw. The authors claim that this is very superior to other microphones both in sensibility, purity of tone and constancy.

1213. TELEPHONE RELAYS. M. Latour. (*British Patent* 142937, February 14th, 1919. Convention date, February 14th, 1918. Patent accepted May 14th, 1920.)

An addition to British Patent 140506 * providing for slight modifications in the connection arrangement of the coupling transformers.

1214. TELEPHONE TRANSMITTER. S. C. Porter. (*French Patent* 489694, June 10th, 1916. Published March 1st, 1919.)

The telephone transmitter is mounted with its diaphragm adjacent to one wall of a resonant chamber whose opposite side is open. This chamber is placed within a second resonant chamber with its open side opposite to the end of the second chamber. The front of the second chamber is open and may be covered by a screen which will allow the passage of sound waves. See also British Patent 100689.

1215. TELEPHONE TRANSMITTER. A. Vaugean, A. de Lavendeyra, and W. Garthwaite. (*French Patent* 502437, September 4th, 1915. Published May 14th, 1920.)

This specification describes a telephone transmitter in which the microphone is constituted by one or more very light cases, for example, of glass, containing spheres of carbon.

1216. A DUPLEX RADIOTELEPHONE SET. M. B. Sleeper. (*Everyday Engineering Magazine*, 9, pp. 256—258, June, 1920.)

See pp. 751—753 in this issue for abstract.

* See RADIO REVIEW Abstract No. 897, October, 1920.

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1217. WIRELESS TELEPHONY. (*La Nature*, 48 (1), Supplement, p. 161, May 29th, 1920.)
A short note referring to the inception in France of wireless telephony tests carried out between London and Rome.

1218. HIGH-POWER WIRELESS IN ARGENTINA. (*Times Trade Supplement*, 6, No. 1010, p. 577, August 14th, 1920. *Electrical Review*, 87, p. 245, August 20th, 1920—Abstract.)
Refers to the formation of a wireless company in Argentina under German financial control for the establishment of direct radio communication with Nauen.

1219. WIRELESS TELEPHONY ON SEABOARD. (*Science and Invention*, 8, p. 404, August, 1920.)
A short illustrated description of some seaboard installations.

1220. EXPERIMENTS WITH WIRELESS HIGH SPEED TELEGRAPHY. F. Kiebitz. (*Telegraphen- und Fernsprech-Technik*, 9, p. 90, August, 1920.)
A description of a receiving system very similar to that described by Banneitz,* the principal difference being in the use of an ironless tuned intermediate circuit of the telephone frequency, with the object of reducing interference.

1221. THE THERMIONIC VALVE IN WIRELESS TELEGRAPHY AND TELEPHONY. J. A. Fleming. (*Nature*, 105, pp. 706—720, August 5th, 1920.)
Abstract of lecture delivered at the Royal Institution on May 21st, 1920, summarising the stages in the discovery and development of the triode valve and including a description of the author's five-electrode valve relay.†

1222. KEYING DEVICE FOR WIRELESS TELEGRAPHY. C. Lorenz. (*German Patent* 298872, April 1st, 1916. Patent granted, October 4th, 1919. Addition to German Patent 195029. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 505—506, June, 1920.)
An ordinary Morse contact key which is inserted in parallel with a glow lamp resistance directly in the antenna circuit. When the key is pressed the lamp is short circuited. The device ensures a constant load on the generator.

1223. THE MANUFACTURE OF HIGH-VACUUM TUBES. (*Telefunken Zeitung*, 4, No. 19, pp. 14—26, and No. 21, pp. 5—20, July, 1920.)
A popular well illustrated description of the various processes in the construction of high-vacuum tubes, including illustrations of a number of types of tube.

1224. VACUUM TUBE AMPLIFIERS. M. Latour. (*Electrical World*, 76, p. 241, July 31st, 1920.)
Correspondence relative to an article by M. C. Batsel in the *Electrical World* for March 29th, 1919, describing radio frequency valve amplifying apparatus manufactured by the Signal Corps, U.S.A. The writer states that the amplifiers described are only reproductions of apparatus designed by him for the French Military Telegraphs in 1916.

1225. THE VACUUM TUBE IN RADIOTELEPHONY. J. Scott-Taggart. (*Electrician*, 85, pp. 301—303, September 10th, 1920.)
The author points out that the essence of radiotelephony lies in the provision of an adequate modulation system for controlling the high-frequency energy. This article briefly summarises the various modulation methods that have been proposed, and is divided into the following heads: Amplification of the Modulated Energy, Grid Potential Modulation, Anode Potential Modulation, Absorption Method, the Triode as a Variable Conductor of Continuous Oscillations, Choke Control Methods. No new methods are dealt with, and in the description of the last one the designation of the valves appears to be in error.

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* See RADIO REVIEW Abstract No. 1065, November, 1920.
† RADIO REVIEW Abstracts No. 805, September, and No. 976, October, 1920.

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1226. PHENOMENA IN OXIDE-COATED FILAMENT ELECTRON TUBES. H. D. Arnold. (*Physical Review*, 16, pp. 70—82, July, 1920.)
See pp. 745—750 in this issue for abstract.
The original contains an extensive bibliography of the subject.

1227. VACUUM VALVES AND VALVE CIRCUITS. A. V. Ballhatchett. (*Model Engineer*, 43, pp. 232—236, September 16th, 1920.)
A short account of various types of valves with circuit diagrams explaining their use. A Round valve, a Q valve, an audion and a French valve are illustrated.

1228. A NEW METHOD OF MEASURING VERY HIGH VACUA. H. Riegger. (*Zeitschrift für technische Physik*, 1, pp. 16—19, January, 1920.)
A description of a new instrument on the Knudsen principle. Current is passed through a circular heater below which is placed an aluminium disc carrying inclined vanes around its periphery; this wind-mill, which is suspended by a fine tungsten wire, is rotated by bombardment of the gas molecules rebounding from the heater. The disc carries a scale and is damped by means of an external electromagnet. An instrument with a period of three minutes could measure vacua of 10^{-6} to 10^{-7} mm., but the reliability of its readings has yet to be investigated.

1229. HIGH-VACUUM PUMPS. A. Gehrts. (*Zeitschrift für technische Physik*, 1, pp. 61—71, March, 1920.)
An illustrated description with extensive bibliography of the recent advances in high vacuum pumps, especially those of the condensation type. A description is given of a pump made by Siemens and Halske of the type first described by Gones and Russell in which the mercury is vaporised by means of an arc.

1230. ELECTROTHERAPEUTIC APPARATUS. W. L. Carlson and E. C. Hanson. (*U.S. Patent* 1338812, July 12th, 1919. Patent granted May 4th, 1920.)
Describes the use of a three-electrode valve for generating sustained oscillations for electro-medical application.

1231. THE PRODUCTION OF HIGH D.C. VOLTAGES WITHOUT TRANSFORMERS. H. Greinacher. (*Bulletin der Schweizerische Electrotechnische Verein*, 11, pp. 59—66, March, 1920. *Elektrotechnische Zeitschrift*, 41, p. 759, September 23rd, 1920—Abstract. *Science Abstracts*, 23B, pp. 244—245, Abstract No. 486, May 31st, 1920—Abstract. *Technical Review*, 6, p. 545, June 22nd, 1920—Abstract.)
Schenkel has invented the device shown in Fig. 4 for multiplying up and rectifying a given A.C. supply without the use of step-up transformers.* The thermionic

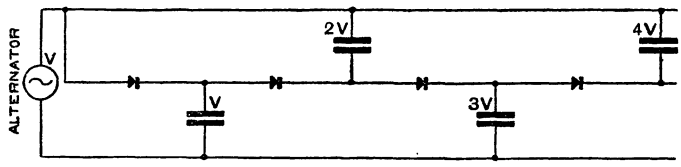

FIG. 4.

rectifiers are shown diagrammatically. This article describes several extensions of this arrangement. The general scheme of one of the improved arrangements is indicated in

* RADIO REVIEW Abstract No. 117, January, 1920. (See also correction, p. 264, February, 1920.)

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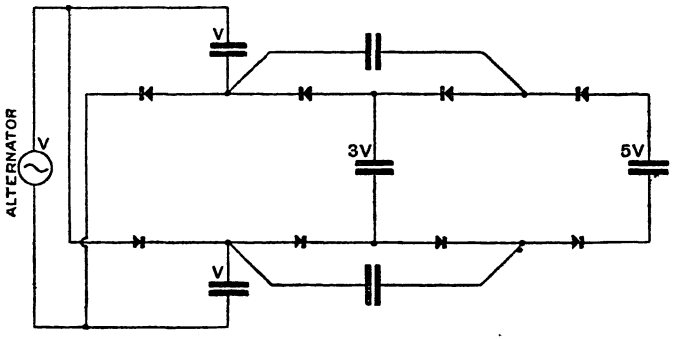

FIG. 5.

Fig. 5. Other arrangements are described for giving even multiples of the supply voltage and experimental results which confirm the theory.

1232. DIRECTIVE WIRELESS TELEGRAPHY. F. Kiebitz. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 46—50, June, 1920.)

A paper read before the telegraph section of the Elektrotechnische Verein, Berlin, giving a historical survey of the subject and a brief discussion of the applications of directive telegraphy to aeroplanes and to the guidance of ships. Scheller's method * and a modification of it are discussed at some length. The methods were illustrated by a number of experiments with waves of 1 or 2 metres length. In the discussion that followed, the principal subject was the Marconi bent antenna, which Seibt maintained had a directive action *per se*, whereas Kiebitz and K. W. Wagner insisted that any such action was due to resistance in the earth beneath the antenna.

1233. AN IMPROVEMENT IN FRAME AERIAL DIRECTION FINDERS. J. de Mare. (*La T.S.F. Moderne*, 1, pp. 148—150, August, 1920.)

The author describes a modification of the ordinary polar reception curve of a frame aerial which results from earthing one terminal of the frame. The application of this modification to direction finding is then described and a circuit diagram of the arrangement given. (Compare also RADIO REVIEW Abstract No. 946, October, 1920.)

1234. DIRECTION FINDING BY RADIO. (*Scientific American*, 122, p. 669, June 19th, 1920.)

A short note relative to the errors found in D.F. work on long wavelengths and the influences of transmission overland.

1235. THE APPLICATION OF THE AUSTIN-COHEN FORMULA TO THE SOLUTION OF SOME IMPORTANT PROBLEMS OF RADIOTELEGRAPHIC TRANSMISSION. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 114—125, August, 1920.)

This is a free translation by Franz Tank of a paper by Bouthillon in *Revue Générale de l'Électricité*, 3, pp. 419—425, 1918. On certain simplifying assumptions as to the radiation resistance of the sending antenna and the detector resistance, an expression is obtained for the efficiency of transmission. Various problems are then considered, *e.g.*, given the wavelength and the distance to determine the characteristic magnitudes at the sending and receiving stations; the determination of the range of transmission; the determination of the most efficient wavelength. A graphical method is given which the author claims to be simpler than those already published.

* See RADIO REVIEW Abstract No. 674, August, 1920, for description.

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1236. REPORT OF THE WORK OF THE GERMAN TELEGRAPH EXPERIMENTAL DEPARTMENT BETWEEN 1913 AND 1918. (*Telegraphen- und Fernsprech-Technik*, pp. 69—85, August, 1920.)

A section of this deals with radiotelegraphy, but the reports are very brief and merely summarise the results obtained; the subjects dealt with include the velocity of propagation over dry and damp earth; the directive effect of horizontal aerials with a view to duplex working; the effect of aperiodic and tuned intermediate circuits in eliminating atmospherics; a new method of measuring coupling (in reality a very old method), and the accuracy obtainable by the parallel ohm method of measuring signal strength.

1237. ELECTRIC PHENOMENA OCCURRING IN HIGH LEVELS IN THE ATMOSPHERE. S. Chapman. (*Journal of the Institution of Electrical Engineers*, 57, Supplement, pp. 209—222, October, 1920.)

Paper read before the Institution of Electrical Engineers May 22nd, 1919, and dealing with various phenomena such as ionisation, etc., some of which are of interest in radio theory. As a result of the large number of measurements on auroræ it was shown that the average height at which ionisation appears to begin is about 100 km.

1238. THE UNILATERAL CONDUCTIVITY OF CRYSTALS. F. Streintz and A. Wesely. (*Physikalische Zeitschrift*, 21, pp. 316—321, June 15th, and pp. 367—374, July 15th, 1920.)

A continuation of a previous paper on this subject.* These parts deal very fully with thermoelectric measurements on crystals of silver sulphide.

1239. ON THE CAUSE OF THE EFFECTIVENESS OF RADIATION DETECTORS AND ELECTRON RELAYS. E. F. W. Rasch. (*Physikalische Zeitschrift*, 21, pp. 381—382, July 15th, 1920.)

A reproduction of a letter sent to Ferd. Braun in 1903 on the coherer action due to the heating of conductors of the second class, such as films of oxide and sulphide and suggesting the practical importance of research on the subject in connection with radio-telegraphy.

1240. ELECTRIC CONTACT AND COHERER ACTION. H. Rohmann. (*Physikalische Zeitschrift*, 21, pp. 417—423, August 15th, 1920.)

A device is described whereby the distance between two electrodes can be varied and determined to 1 $\mu\mu$ ($=10^{-10}$ cm). The movable electrode is carried on a short arm near the fixed end of a steel rod the other end of which can be twisted by a long arm against the end of which a fine micrometer screw presses. Tables and curves are given for various electrodes, showing the current for a constant E.M.F. as the distance is varied from 1 to 50 $\mu\mu$, and for a constant distance as the E.M.F. is varied. The latter shows the current to be proportional to the E.M.F. up to a certain point where it increases much more rapidly, probably owing to electrostatic forces closing the contact. The author concludes that current passes before the actual metals make contact, probably through a film of water, but there is no certainty as to the nature of the film. The author thinks that his results disprove the passage of free electrons, but admits that further research on this point is desirable. The author's device allows such fine adjustment that reliable microphone action can be obtained between metals, tungsten and chromium needing no adjustment for hours. If the distance between the electrodes is too small or too great the refinements in the sound are not reproduced. The device lends itself to the study of coherer action.

1241. PHOTOGRAPHIC RECEPTION OF SPARK SIGNALS. J. A. Hoxie. (*Elektrotechnische Zeitschrift*, 41, pp. 733—734, September 16th, 1920.)

A brief reference to reception by means of a reflecting galvanometer and photographic apparatus.

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* RADIO REVIEW Abstract No. 752, September, 1920.

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1242. WIRELESS CALL FOR SHIPS. H. Thurn. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 64—65, July, 1920.)

Describes the automatic call device developed by Marconi's Wireless Telegraph Company, Limited.*

1243. STATIC ELIMINATION BY DIRECTIONAL RECEPTION. G. W. Pickard. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 358—415, October, 1920.)

Paper read before the Institute of Radio Engineers, November, 1919, of which an abstract has already been given.† In the discussion, C. L. Farrand criticised Pickard's use of the phrase "elimination by directional reception" with regard to the circuits proposed by the latter; and also attempted to meet the objections usually raised against the "vertical propagation of static" theory. The argument that the theory fails because a vertical antenna is strongly affected by static is met by the assumption of the generation of "static" currents in the conducting earth.

Details of some experiments carried out with the "Barrage" receiver of Alexanderson ‡ were given by H. H. Beverage who found that the signal-stray ratio was most favourable with the particular adjustment which balanced south-west signals. Tests at Long Island confirmed Pickard's observations that the strays are directional on the North Atlantic coast with a maximum on the south-west horizon.

G. W. Pickard in reply discussed the simple theory that atmospherics are mainly of tropical origin and indicated marked correspondence between the seasonal variation diagrams of thunderstorms and atmospherics in the United States. Directional bearings from two stations on the Atlantic and Pacific coasts apparently locate the source of static somewhere in the vicinity of the Gulf of Mexico. But it is impossible to attribute every stray to a lightning flash as in the United States half a million flashes each day would be required to fit the facts. Although only an inconsiderable portion of static can be attributed to lightning flashes, thunderstorms are probably the sources of many atmospherics because of the high level discharges associated with them. The potential of a thundercloud is of the order of two hundred million volts and from a detailed consideration of these clouds the theory is advanced that the portion of the total static which may be attributed to thunderstorms is due to equalising lateral discharges at an altitude of 50 or 100 kilometres. In this connection L. W. Austin stated that it is difficult to understand how electrical disturbances without visible manifestation can be produced which are more powerful than any known high power station while a lightning flash hardly produces a disturbance twenty miles away.

It has been found by H. H. Beverage that an antenna directive towards the north-east receives only very little grinder static while an antenna directive to the south-west receives very strong grinder static often ten to forty times as strongly. Clicks can usually be attributed to lightning discharges in the neighbourhood.

C. A. Hoxie dealt with some photographic galvanometer records obtained in some experiments carried out with the aim of localising the direction of atmospherics. Considerably more static was obtained on a NE-SW loop than from one placed E-W or one placed NW-SE. A. S. Blatterman from some observations made in New Jersey confirmed Hoxie's statement that the maximum effect is obtained in the SW-NE direction.

F. K. Vreeland pointed out that the balancing system previously suggested by Austin requires that the shock oscillation in the two collectors must agree in magnitude, phase, frequency and decrement. It was difficult to arrange that this should be so in practice. The problem of eliminating the effects of sharp impulsive strays can be met in a simple manner which is not described. Dr. Austin in reply mentioned that disturbances had been met with which indicated that static had sometimes definite wavelengths of its own.

1244. RECEIVER CIRCUIT. U. B. Ross. (*Wireless Age*, 7, p. 27, January, 1920.)

In the circuit described the plate and grid of the detecting valve are connected across the

* See RADIO REVIEW Abstract No. 551, July, 1920.

† RADIO REVIEW Abstract No. 525, July, 1920.

‡ See RADIO REVIEW Abstract No. 75, December, 1919, for description.

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aerial tuning inductance while the aerial shortening condenser completes the grid filament circuit, a separate grid condenser being interposed in the grid lead. The H.T. batteries in series with the telephones are connected between plate and filament in shunt to the antenna circuit. A low-frequency magnifier may be joined across the telephones in the plate circuit of the first valve.

1245. LONG WAVE TUNER AND C.W. RECEIVER AND AMPLIFIER. (*Model Engineer*, 43, pp. 270—272, September 30th, 1920.)

Constructional details are given for a tuner to operate between 150 and 4,500 metres and a single valve detector which may be operated as an autodyne.

1246. QUANTITATIVE EXPERIMENTS WITH COIL ANTENNÆ IN RADIO TELEGRAPHY. L. W. Austin. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 421—423, October, 1920.)

The original paper was first published in the *Journal of the Washington Academy of Sciences*—see RADIO REVIEW Abstract No. 3, October, 1919. In the discussion of the paper as presented to the Institute of Radio Engineers, Dr. J. H. Dellinger refers to the differences in the values of the constants of the transmission formulæ given by Austin and himself (see RADIO REVIEW Abstract No. 4, October, 1919). The Austin antenna to antenna formula is based on the assumption that the ground is a perfect conductor in which case the hypothetical Hertzian oscillator is equal in length to twice the height of the antenna to its centre of capacity. The other formula suggested assumed a Hertzian oscillator having its length equal to the actual height of the antenna above the ground. The truth lies somewhere in between the two. For an antenna on good conducting ground or over salt water there is probably a considerable image effect but in most cases the equivalent oscillator is somewhat less than twice the antenna height.

G. S. Davis expresses the opinion that the development of the use of coil aerials was not due solely to the assistance of valve amplifiers but because of the necessity of developing direction finders for war purposes.

1247. HIGH-FREQUENCY AMPLIFIERS AND FRAME ANTENNÆ. R. Ettenreich. (*Verhandlungen der Deutschen Physikalischen Gesellschaft*, 1, pp. 66—67, June 14th, 1920.)

A brief account of an experimental lecture given at Vienna, illustrating the properties of the triode and the action of a five-stage amplifier in connection with a frame aerial and a separate heterodyne generator. Reference is made to a patent application by E. Schrack for graphite resistances fused into the bulb of the triode for both anode circuit and grid leak.

1248. LOOP ANTENNA FOR SUBMARINES. R. R. Batcher. (*Wireless Age*, 7, pp. 28—31, January, 1920.)

A brief *résumé* of the experiments carried out by J. A. Willoughby and P. D. Lowell. (See RADIO REVIEW Abstract No. 85, December, 1920.)

1249. CHRISTIANIA WIRELESS STATION. (*Telefunken Zeitung*, 4, No. 21, pp. 27—37, July, 1920.)

A description of the recently erected Telefunken Station. The transmitting plant is similar to that at Nauen, with high-frequency generator and frequency transformers; the power delivered to the antenna is 15 kW, and the wavelengths 4,000, 5,400 and 8,000 metres. The article is well illustrated and photographs are given of the accumulation of snow and ice on the aerial towers, etc. This has necessitated a modification in the original scheme, an extra tower having been erected to halve the span.

1250. WIRELESS HALF WAY ROUND THE WORLD. J. W. Kean. (*Scientific American*, 122, pp. 698 and 712, June 26th, 1920.)

A description of the work of building and equipping the Bordeaux (Lafayette) Radio Station with some particulars of the plant, towers, power supply, etc.

1251. THE WIRELESS STATION AT NAUEN. G. Arco. (*Revue Générale de l'Électricité*, 7, p. 198D, June 19th, 1920—Abstract.)

See RADIO REVIEW Abstract No. 531, June, 1920.

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1252. THE HIGH FREQUENCY MACHINE AND TRANSFORMERS AT NAUEN. W. Dornig. (*Telefunken Zeitung*, 3, No. 17, pp. 65—74, August, 1919.)
An illustrated descriptive article—for abstract of which see RADIO REVIEW Abstract No. 532, July, 1920.

1253. THE LARGE WIRELESS STATIONS. A. Bocquet. (*Bulletin de la Société Belge des Electriciens*, 34, pp. 176—180, August, 1920.)
A summary is given of the recent rapid development of large wireless stations in France and on the increase of sensitiveness of receiving apparatus arising through the use of the three-electrode valve. It is stated that using a valve an audible signal can now be obtained over a received energy of only 0·000,000,001 microwatt. Developments in the large French wireless stations are briefly summarised.

1254. LARGE GERMAN WIRELESS STATION. (*Elektrotechnische Zeitschrift*, 41, p. 677, August 26th, 1920.)
Germany possesses three large stations suitable for transocean service, Nauen, Eilvese and Königswusterhausen, of which the former is the largest in the world and can communicate with the antipodes, a distance of 20,000 kms. The technical equipment of these stations cannot be fully utilised because suitable stations abroad are neither numerous nor powerful enough.

1255. DEVELOPMENT OF THE GERMAN NETWORK OF WIRELESS STATIONS. (*Elektrotechnische Zeitschrift*, 41, p. 534, July 8th, 1920.)
Gives a list of the towns in which the stations are now installed with the object of relieving the telegraph lines throughout the country.

1256. WIRELESS TELEGRAPHY IN THE GERMAN COLONIES. (*Telefunken Zeitung*, 4, No. 21, pp. 48—57, July, 1920.)
A lecture given to the officers of the Telegraph Corps by Dr. Roscher, describing the pre-war scheme for an imperial network, the development up to the outbreak of war, the service rendered by the stations during the war and the ultimate loss of all the stations.

1257. THE WINDHUK RADIO STATION DURING THE WAR. W. Thiess. (*Telefunken Zeitung*, 4, No. 21, pp. 43—47, July, 1920.)
A non-technical description of the arrival of the news of the outbreak of war while the station was still undergoing its test after completion, of the reception of messages from Nauen (8,500 km) after Kamina (Togoland) had fallen, of the capture of Windhuk by the Union troops on May 1st, 1915, after the receiving apparatus and several essential parts of the sending apparatus had been removed to Tsumeb, and of the capture of this latter place a few months later.

1258. THE ELECTRICAL EQUIPMENT OF THE "VATERLAND." (*Electrician*, 85, p. 160, August 6th, 1920. Abstracted from *Elektrotechnische Zeitschrift*.)
Reference is made to the wireless telegraph installations, of which the vessel carries three, including a high frequency alternator.

1259. WIRELESS STATIONS IN CHINA. (*Elektrotechnische Zeitschrift*, 41, p. 557, July 15th, 1920.)
The Ministry of Communications has given permission to a number of companies in China to erect wireless stations to be used solely for commercial purposes. Stations are being erected under the direction of a British engineer for communication between Pekin and Chinese Turkestan.

1260. WIRELESS TELEGRAPHY IN ECUADOR. (*Elektrotechnische Zeitschrift*, 41, p. 557, July 15th, 1920.)
The Société Française Radio-Électrique have erected a 10 kW station at Quito for the Government; similar stations are being erected at Guayaquil and Esmeralda. The private importation and erection of wireless apparatus is forbidden.

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1261. A PORTABLE WIRELESS SET. (*Scientific American*, 122, p. 697, June 26th, 1920.)

Reference is made to a portable transmitting receiver using a loop aerial and crystal detector with a sending range from 10 to 12 miles.

1262. LIFEBOAT WIRELESS SET. C. Gruner. (*Telefunken Zeitung*, 4, No. 21, pp. 57—59, July, 1920.)

A description of a Telefunken set suitable for a 10 metre boat with a 6 metre mast. The double-hand-driven generator gives 500 cycles per second at 72 revs. per minute. It is a quenched gap system tuned to 300 and 600 metres wavelength.

1263. THE WIRELESS TELEPHONE RECEIVING STATIONS AT STOCKEL. (*Bulletin de la Société Belge des Electriciens*, 34, pp. 120—121, April—June, 1920.)

Some notes are given as to the installation at the Belgian station at Stockel. A frame aerial is used together with valve amplifiers and separate heterodyning when required.

1264. THE ROME WIRELESS STATION. (*Scientific American*, 123, p. 207, August 28th, 1920.)

A short note referring to the installation at Rome using arc transmitters.

1265. HIGH-POWER WIRELESS IN CANADA. (*Electrical Industries*, 20, p. 1276, October 6th, 1920.)

A short note referring to the preparations for building a huge experimental radio station near Toronto for communication between Canada and England.

1266. WIRELESS PLANT TO BE ERECTED IN MEXICO. (*Telegraph and Telephone Age*, 38, p. 425, August 1st, 1920.)

Refers to a scheme for the erection of four new wireless stations in Mexico.

1267. LIGHTSHIPS TO HAVE WIRELESS. (*Wireless Age*, 7, p. 8, January, 1920.)

Refers to the need for installing wireless apparatus on all of the sixty-seven lightships stationed round the U.S. coast.

1268. AN EFFICIENT PLAIN AERIAL RECEIVER. A. Cooper. (*Wireless World*, 8, p. 224, June 26th, 1920.)

1269. WIRELESS IN THE A.E.F. L. R. Krumm and W. H. Taylor. (*Wireless Age*, 7, pp. 12—19, January, 1920; pp. 10—14, April, 1920.)

In Part III.* some of the D.F. and intercepting stations installed in France are described and illustrated. Circuit diagrams of the French amplifier type R. 2 bis, type 3 ter, type No. 3, type L. 3 and of wavemeters types 2 and 3 are given.

In Part IV. buzzer signalling stations and trench listening stations are described. A circuit diagram is given of the French type 3 ter amplifier.

1270. WINDING AND TAPPING RADIO COILS. L. M. Lafave. (*Wireless Age*, 7, p. 28, January, 1920.)

Simple constructional details are given.

1271. WINDING INDUCTANCES OF HONEYCOMB CROSS SECTION. E. L. Sweet. (*Wireless Age*, 7, p. 27, January, 1920.)

Details are given for building a former upon which honeycomb pattern of inductances may be wound by hand.

1272. CONDENSER. W. Dubilier. (*French Patent* 502095, July 29th, 1919. Published May 4th, 1920.)

The condenser is enclosed in a metal casing and a compressor member is provided for adjusting the pressure on the condenser elements. The casing is provided with an insulating cover, the under surface of the cover and the upper surface of the compressor member having corrugations to prevent creepage from the terminal passing through the centre of the cover to the walls of the casing. The terminal is surrounded by an insulating bush and the casing is filled with a molten wax or similar insulating compound. There is a corresponding British application No. 130595, the patent on which has not yet been granted.

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* See RADIO REVIEW Abstract No. 194, February, 1920, for abstract of first parts.

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1273. LINEAR VARIABLE CONDENSERS FOR WIRELESS WORK. (*Electrical World*, 75, p. 1225, May 22nd, 1920.)

A variable condenser manufactured by the International Radio Telegraph Company is briefly described and illustrated.

1274. RADIO FREQUENCY INDUCTANCE COILS. M. Z. Zinn. (*Wireless Age*, 7, pp. 21—23, May, 1920. *Science Abstracts*, 23B, p. 326, Abstract No. 644, June 30th, 1920. *Electrical World*, 76, p. 33, May 3rd, 1920—Abstract.)

This paper discusses some of the practical considerations which enter into the design of coils for high-frequency circuits. The influence of distributed capacity and of skin effect are considered in increasing the effective resistance of the coil. Impedance measurements are given of a coil at various frequencies using a radio frequency bridge which is described. It is concluded that for wavelengths above 5,000 metres a multilayer coil is many times more efficient than a single layer one, but that for short wavelengths a single layer coil is the best.

1275. INDUCTANCE. Société Française Radio-Électrique. (*French Patent* 488195, November 11th, 1915. Published September 10th, 1918.)

The invention consists essentially in a switch for controlling the relative arrangement of two inductances used in wireless signalling. The switch has two concentric rows of contacts and rotating arms which are so connected that the two inductances may be connected in parallel with opposed fluxes, in series with opposed fluxes, or in series with adding fluxes.

See also British Patent 102148.

1276. HIGH INDUCTANCE VARIOMETERS. (*Everyday Engineering Magazine*, 9, p. 159, May, 1920.)

Constructional details of a variometer of the sliding coil type.

1277. TELEPHONE. Naamlooze Vennootschap de Nederlandsche Thermo-Telephoon, Maatschappij. (*French Patent* 488967, February 19th, 1918. Published December 3rd, 1918.)

This specification describes a thermal-telephone and thermal-microphone. The novel feature consists in covering the conductors of the hot wire transmitter and receiver with a skin of insulating or poorly conducting material. See also British Patent 114418.

1278. ADJUSTABLE TUNED TELEPHONE RECEIVER. G. Seibt. (*Elektrotechnische Zeitschrift*, 41, pp. 625—627, August 12th, 1920. *Technical Review*, 7, p. 144, November 2nd, 1920—Abstract.)

A description of a receiver designed for earth signalling during the war. The number of such sets was so great that to prevent interference it was desirable to work at different frequencies and use highly resonant receivers tuned to the appropriate frequency. The resonance curve of the ordinary receiver is very flat. A receiver with two tuned diaphragms, the outer one operated by the ordinary one through the layer of air between them was tried but given up in favour of the type described which also has two steel diaphragms which, however, are rigidly connected at their centres by a screwed pin, the rotation of which forces them apart and thus alters their tension and natural frequency. The edges between which they are clamped are so rounded that, as the diagrams are forced apart, their effective diameter is decreased, thus giving a wider range of natural frequencies which can be adjusted between 450 and 1,400 per second. To increase the resonance, the diaphragms are weighted at their centres. Photographs of the complete receiver are given but no definite figures to enable one to compare the sensitiveness of the receiver with that of the ordinary type.

1279. TELEPHONE RECEIVER. A. Vaugean, A. de Lavendeyra and W. Garthwaite. (*French Patent* 502436, September 4th, 1915. Published May 14th, 1920.)

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1280. HOW TO MAKE A TELEPHONE TRANSFORMER. A. D. Kent. (*Wireless World*, 7, pp. 699—700, March, 1920. *Technical Review*, 6, p. 342, April 13th, 1920—Abstract.)

Constructional details with particulars of the core and windings are given for a telephone transformer having a primary resistance of 4,500 ohms and a secondary of 60 ohms.

1281. THE DESIGN AND CONSTRUCTION OF AN AMATEUR RECEIVING SET. A. D. Kent. (*Wireless World*, 7, pp. 536—540, December, 1919.)

1282. A CRYSTAL RECEIVER WITH VALVE MAGNIFIER. (*Wireless World*, 8, pp. 64—66, April 17th, 1920; pp. 99—101, May 1st, 1920; pp. 139—140, May 15th, 1920.)

Constructional details are given with particulars of the windings, condensers, etc.

1283. AUDION VACUUM TUBE DETECTOR. (*Electrical World*, 75, p. 1290, May 29th, 1920.)

A short illustrated note describing a single valve detector unit manufactured by the International Radio Telegraph Company, New York.

1284. AMPLIFYING RADIO TRANSFORMERS. (*Electrical World*, 76, p. 104, July 10th, 1920.)

A short illustrated note describing a transformer with a ratio of 4 to 15 wound on a laminated iron core and with primary and secondary resistances of 1,000 and 5,000 ohms respectively, manufactured by A. H. Corwin and Company, New Jersey.

1285. THE DESIGN AND CONSTRUCTION OF A WAVEMETER AND TUNING SET. A. D. Kent. (*Wireless World*, 8, pp. 8—12, April 3rd, 1920.)

Dimensions and constructional details are given for a simple wavemeter having five fixed condenser units which may be connected in parallel and a variometer type of inductance for tuning purposes.

1286. TELEGRAPHING WITH INVISIBLE RAYS OF HEAT. J. Stuart. (*Popular Science Monthly*, 97, p. 51, September, 1920.)

A short illustrated description of photophonic apparatus utilising heat rays. For reception purposes a small platinum-tellurium thermo-electric couple is described for use in conjunction with a three-valve amplifier. The thermo-couple is enclosed in a glass cell with a fluorite window. See also RADIO REVIEW Abstract No. 71, November, 1919.

1287. LIGHT-SENSITIVE ELECTRIC DEVICE. T. W. Case. (*French Patent* 499913, September 24th, 1918. Published February 26th, 1920.)

An electric resistance sensitive to light rays both visible and invisible is formed of a compound of thallium and sulphur, preferably, thallium oxy-sulphide.*

1288. LIGHT-SENSITIVE ELECTRIC DEVICE. T. W. Case. (*French Patent* 499914, September 24th, 1918. Published February 26th, 1920.)

A light-sensitive resistance comprising a compound of thallium and sulphur is spread over a disc of quartz or silica at a high temperature. Preferably, thallium oxy-sulphide is employed. The disc may be enclosed in a vessel from which moisture is removed and which may be exhausted.†

1289. A COMPENSATED SELENIUM CELL. W. S. Gripenberg. (*Elektrotechnische Zeitschrift*, 41, pp. 453—454, June 10th, 1920. *Technical Review*, 6, p. 786, September 28th, 1920—Abstract.)

A new form of selenium cell is described which is provided with three electrodes one of which is opaque and the other cut up into strips to allow the light to pass through to the selenium film beneath. The third electrode which is mounted underneath the selenium film forms

* See also British Patent 133403—RADIO REVIEW Abstract No. 460, June, 1920.

† See also British Patent 133404—RADIO REVIEW Abstract No. 460, June, 1920.

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the common electrode, and the selenium film is thus divided into two branches connected differentially to the output circuit. The normal current through the indicating apparatus can thereby be reduced to zero.

1290. ON THE RECORDING AND REPRODUCING SOUNDS BY MEANS OF LIGHT. A. O. Rankine. (*Proceedings of the Physical Society of London*, 32, pp. 78—83, February 15th, 1920. *Science Abstracts*, 23A, p. 351, Abstract No. 895, June 30th, 1920—Abstract.)

1291. THE FESSENDEN OSCILLATOR. E. T. Jones. (*Electrical Experimenter*, 7, pp. 1020 and 1090, February, 1920.)

An illustrated description giving details of the construction of the Fessenden oscillator for submarine sound signalling.

1292. AN ELECTRICAL SIGNALLING METHOD FOR GUIDING AERIAL AND MARINE CRAFT. R. H. Marriott. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 345—357, October, 1920.)

Paper read before the Institute of Radio Engineers, November, 1919—see RADIO REVIEW Abstract No. 578, July, 1920, for abstract.

1293. AN OSCILLOGRAPHIC INVESTIGATION OF MICROPHONES FOR UNDER-WATER RECEPTION. P. Ludewig. (*Physikalische Zeitschrift*, 21, pp. 305—311, June 15th, 1920.)

1294. GUIDING SHIPS BY ELECTRIC CABLES. N. Tevis. (*Scientific American*, 123, pp. 123 and 138, August 7th, 1920.)

Refers to an installation at Portsmouth of the method of guiding ships in and out of harbour by means of a submerged cable carrying alternating current.

1295. FLYING IN MIST AND FOG. H. Harper. (*Times Trade Supplement*, 7, p. 66, October 2nd, 1920.)

The great utility of wireless telephony installations for commercial aircraft is referred to together with the good results recently obtained in this direction on the cross-Channel air services.

1296. WIRELESS TELEGRAPHY IN SPITZBERGEN. (*Elektrotechnische Zeitschrift*, 41, p. 514, June 30th, 1920.)

According to Article 4 of the Spitzbergen agreement between the allied and neutral powers, any public wireless station erected on the island by the Norwegian Government or under their protection, shall work without distinction with ships of all the signatory powers. Landowners in Spitzbergen have the right to erect private stations and work with other fixed or moving stations including those on ships or aircraft.

1297. CLASSIFICATION OF FREQUENCIES. (*Bulletin de la Société Belge des Electriciens*, 34, p. 187, August, 1920.)

The French delegates to the International Electrotechnical Commission have recommended the following classifications for currents of various frequencies, the figures given being cycles per second :—Very low frequency, 1—10 ; low frequency, 11—100 ; medium frequency, 101—1,000 ; high frequency, 1,001—10,000 ; very high frequency, 10,001—100,000 ; extra high frequencies, above 100,000.

1298. CLASSIFICATION FOR SUBJECTS IN RADIO SCIENCE. (*Journal of the American Institute of Electrical Engineers*, 39, p. 341, April, 1920.)

Refers to a proposed classification scheme for articles, books, MSS., etc., dealing with radio work. Reference is made to the main classification headings but the details are not given.

1299. RADIO RESEARCH. (*Electrician*, 85, p. 187, August 13th, 1920.)

In connection with the Department of Scientific and Industrial Research and the Radio Research Board four sub-committees have now been established dealing respectively with the propagation of wireless waves, with atmospherics, with directional wireless and with thermionic valves. The membership of these committees is set out in this note.

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1300. THE WORLD'S LARGEST RADIO STATION. (*Telegraph and Telephone Age*, 38, p. 332, June 1st, 1920. *Electrical World*, 75, p. 1209, May 22nd, 1920; also 76, p. 146, July 17th, 1920—Abstract. *Technical Review*, 6, p. 659, August 3rd, 1920—Abstract. Also *Scientific American*, 123, pp. 79—92, July 24th, 1920. *Telegraph and Telephone Age*, 38, pp. 421—423, August 1st, 1920—Abstract. *Electrical Review*, 87, p. 16, July 2nd, 1920—Abstract. *L'Électricité*, 2, p. v, August 15th, 1920—Abstract. *Elektrotechnische Zeitschrift*, 41, p. 716, September 9th, 1920.)

Reference is made to a proposal for the installation of what will be the largest radio station in the world at Rocky Point, L.I. It is stated that the station will have five separate communication routes, viz., with Argentina, with France, with Scandinavia, with Germany and with Italy.

1301. WIRELESS TELEGRAPHY, FRANCE. (*Electrical Review*, 87, p. 241, August 20th, 1920. *L'Électricité*, 2, pp. III—V, June 15th, 1920. *La T.S.F. Moderne*, 1, p. 167, August, 1920—Abstract. *Scientific American*, 123, p. 149, August 4th, 1920—Abstract. *Electrical Industries*, 20, pp. 758—759, June 16th, 1920—Abstract.)

A short note referring to a recent statement by M. Deschamps on the subject of the French wireless network for linking up France with its colonies and with other countries of the world.

1302. WIRELESS IN THE ILES DE TONGA. (*Journal Télégraphique*, 44, p. 16, January 25th, 1920. *Elektrotechnische Zeitschrift*, 41, p. 573, July 22nd, 1920—Abstract.)

Refers to a contract made with the Amalgamated Wireless (Australasia), Ltd., for the establishment of a complete wireless network.

1303. WIRELESS IN FOREIGN TRADE. (*Wireless Age*, 7, pp. 10—11, January, 1920.)

Refers to the valuable influence of radio-communication in promoting international commerce and deals with the proposed programmes of the Radio Corporation of America.

1304. WIRELESS IN CHINA. (*Scientific American*, 123, p. 207, August 28th, 1920. *Times Trade Supplement*, 7, p. 33, September 25th, 1920. *Wireless Age*, 8, p. 9, October, 1920.)

A short note referring to the opening of a new wireless station at Temple of Heaven in Peking. It is also stated that a station at Urga in Mongolia is expected to be ready for service some time in October.

1305. WIRELESS TELEGRAPHY IN INDO-CHINA. (*Elektrotechnische Zeitschrift*, 41, p. 573, July 22nd, 1920.)

A note referring to the establishment of direct wireless communication between the Eiffel Tower and stations in Indo-China and South China.

1306. SHIP MESSAGES COVER 6,339 MILES. (*Wireless Age*, 7, p. 9, February, 1920.)

Reference is made to a record signalling range from a Pacific mail liner.

1307. THE ELECTRICAL TRANSMISSION OF PICTURES. P. R. Coursey. (*Nature*, 106, pp. 115—116, September 23rd, 1920.)

A brief summary of the various methods including a reference to the possibilities of radio transmission.

1308. WIRELESS INCENDIARY? (*Scientific American*, 122, p. 701, June 26th, 1920.)

Correspondence relative to the possibility of induced currents from powerful wireless stations causing fires at oil wells.

1309. INTERPLANETARY WIRELESS. G. Pessioni, Q. Majorana. (*L'Elettrotecnica*, 7, pp. 354—355, July 5th, 1920.)

Correspondence relative to the article by Q. Majorana on this subject.*

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* See RADIO REVIEW Abstract No. 855, September, 1920.

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1310. WIRELESS WAVES AND WAVE MOTION. (*Wireless World*, 8, April 3rd, 1920.)

1311. C.W. TIME SIGNALS. (*La Nature*, 48, Supplement, p. 177, June 12th, 1920. *Wireless World*, 8, p. 279, July 10th, 1920.)

Particulars are given of the time signals sent daily to the *Aldebaran* at 8.45 from Lyons Station, on 15,500 metres, and from Nantes at 8.23 and 20.23 on 9,000 metres, and at 10.23 and 20.53 on 11,000 metres.

1312. RECEPTION OF W/T TIME SIGNALS AT THE ROYAL OBSERVATORY, GREENWICH. W. Bowyer. (*Monthly Notices of the Royal Astronomical Society*, 80, pp. 648—650, May, 1920.)

Time signals transmitted by wireless telegraphy were received at the Royal Observatory in 1912 when a two-circuit receiving set with crystal detector was erected by the Admiralty. The possibilities of automatic registration of the signals were considered in 1914 using Brown relays and a syphon recorder but this work was suspended until late in 1919 when a new installation was fitted. The apparatus at present installed consists of a Marconi seven-valve amplifier with a range of 600 to 5,000 metres wavelength using naval pattern R5 valves, and a seven-valve R.A.F. pattern amplifier covering a range from 4,000 to 18,000 metres using French valves. A separate heterodyne is used for C.W. reception. Aerial—two wire total length about 260 yards. Capacity—about 0·0023 microfarad; total tuning inductance 20,000 microhenries; total tuning capacity in parallel with inductance 0·018 microfarad. Intermediate circuit—total inductance 20,000 microhenries; variable condensers 0·018 microfarad. Circuit to grid of first valve—total inductance 70,000 microhenries; variable condensers of total capacity 0·018 microfarad. A three-circuit receiver is employed. A number of tables are given of readings comparing the Eiffel Tower signals with each other and with the standard clocks at Greenwich the differences in most cases being very small, but in some instances rather large discrepancies were observed for which no explanation has been found.

1314. AUTOMATIC SENDING DEVICE INSTALLED IN THE ALIPUR OBSERVATORY, CALCUTTA. (*Radio Review*, 1, pp. 432—434, June, 1920. *Technical Review*, 6, p. 659, August 3rd, 1920—Abstract.)

1315. WIRELESS COMMUNICATION BETWEEN GERMANY AND HOLLAND. (*Elektrotechnische Zeitschrift*, 41, p. 778, September 30th, 1920.)

A regular twenty-four-hour service is now established between Düsseldorf and Rotterdam; the tariff is the same as for line telegraphy.

1316. WIRELESS WEATHER SERVICE. J. Georgi. (*Telefunken Zeitung*, 4, No. 21, pp. 38—42, July, 1920.)

A review of the application of wireless telegraphy to the collection and distribution of meteorological reports (1) before, (2) during, and (3) after the war.

1317. EXPERIMENTS ON THE DISTRIBUTION OF REPORTS BY WIRELESS TELEPHONY. W. Hahn. (*Elektrotechnische Zeitschrift*, 41, pp. 727—729, September 16th, 1920.)

Experiments made in April and May by sending out reports from Königswusterhausen (near Berlin) by means of a Poulsen-Lorenz arc. The height of the aerial is 150 metres, the wavelength 3,700 metres and the aerial current varied between 10 and 30 amperes when speaking. Frame aerials cannot be used for reception in towns owing to the disturbing factors which affect the amplifiers, therefore elevated antennæ were employed. Telephony does not demand such a highly trained personnel for reception as telegraphy. The results obtained at twenty-three stations up to a distance of 600 km were that (*a*) the loudness was sufficient, (*b*) the method of first reading the report quickly and then slowly for copying, spelling names, etc., was found satisfactory, (*c*) men's and women's voices are equally good, (*d*) detectors without amplifiers were not successful above 250 km; (*e*) practice is necessary in receiving to obtain the best results, (*f*) the greatest trouble was caused by spark stations causing interference.

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1318. THE AMATEUR'S GUIDE TO THE ETHER. (*Wireless World*, 8, pp. 97—98, May 1st, 1920; also p. 116 and p. 134, May 15th, 1920.)

A table of the principal transmission times for the most important wireless stations. Wavelengths, time of transmission and other particulars are given.

1319. THREE-VALVE RESISTANCE AMPLIFIER. R. Quentin. (*L'Électricien*, 51, p. 382, September 1st, 1920.)

A short note describing the constructional arrangement of a three-valve resistance capacity coupled amplifier and giving also winding details and dimensions for an intervalve transformer for a low frequency amplifier.

1320. SUBMARINE SOUND SIGNALLING. M. I. Pupin. (*British Patent* 139498, February 25th, 1920. Convention date, February 4th, 1918. Patent not yet accepted but open to inspection.)

Part of the arrangement is a multi-stage valve amplifier comprising filtering circuits for cutting out low frequency impulses and transmitting high frequency ones, using resistances shunted by inductive leaks,—see also RADIO REVIEW Abstract No. 1174, November, 1920. A similar filter circuit for transmitting low frequency currents and stopping high frequency ones is also described. In this case a number of equal resistances are joined in series, while equal shunting condensers are provided to drain off the high frequency impulses, the arrangement being similar to that described in Abstract No. 1174 with the resistances and condensers interchanged.

1321. VACUUM TUBE AMPLIFICATION. P. H. Boucheron. (*Electrical Experimenter*, 7, pp. 1158—1159 and 1204—1205, March, 1920.)

Various arrangements of cascade multi-stage amplifiers are described. The use of resistance-capacity, choke coil, and transformer intervalve coupling is dealt with both for high and low frequencies.

1322. V.T. DETECTOR AND FOUR-STAGE AMPLIFIER RESISTANCE COUPLED. C. R. Keutz. (*Wireless Age*, 7, pp. 24—26, January, 1920.)

Constructional details are given of four and five-stage resistance capacity coupled amplifiers, together with illustrations of instruments built to the plans described.

1323. PHOTOELECTRIC PHOTOMETER. A. H. Compton. (*Transactions of the Illuminatin Engineering Society*, 15, pp. 28—33, February 10th, 1920. *Electrical World*, 75, p. 1100, May 8th, 1920—Abstract.)

Refers to the use of a triode amplifier for magnifying the readings of a photo electric cell used for photometry.

1324. AMPLIFIER FOR ALTERNATING CURRENTS. F. Skaupy. (*German Patent* 310012, June 9th, 1918. Patent granted October 17th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 169—170, February, 1920.)

An amplifier in which the so-called Hall effect is used. The current to be amplified circulates in a coil C, Fig. 6, thus providing a magnetic field in which is situated a conducting surface

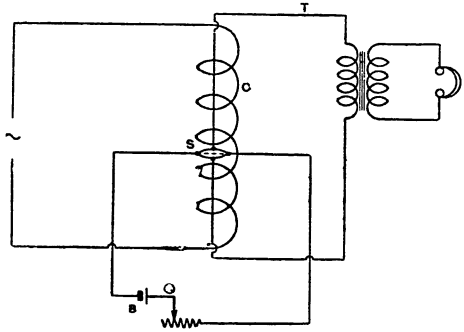

FIG. 6.

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S of tellurium or bismuth through which a current from a local battery B flows. The action of the magnetic field is to produce a transverse electromotive force in the conducting surface. This electromotive force acts in the telephone circuit T in which the amplified current flows (see Fig. 6).

1325. HIGH FREQUENCY TELEPHONY IN HIGH VOLTAGE OVERHEAD POWER DISTRIBUTING SYSTEMS. Gewecke. (*Elektrotechnische Zeitschrift*, 41, pp. 670—672, August 26th, 1920.)

The author is an engineer of the Telefunken Company and he gives an illustrated description of a system which they have developed and installed in a number of power stations. The sending and receiving apparatus is of the ordinary type employing thermionic valve generators and detectors. The power required is only 10 to 20 watts and no amplification has been found necessary for a distance of 135 kilometres between the power station at Golpa and the substation at Rummelsburg. The antenna consists of a wire supported between two of the masts underneath the power lines, the earth terminal being connected to one of the masts. The power lines pick up and guide the waves. The valves only burn when speaking, the calling device consisting of a crystal detector operating a relay and trembling bell, which is operated as soon as the transmitting valve is set oscillating. Speech is little affected by the breakage of two of the three power lines and is still practicable, if the remaining wire is earthed at some intermediate point or even if intermittent discharges and arcs are occurring which would make ordinary wire telephony impossible. The system is economical and as simple to operate as ordinary telephony; the author considers that it has a large future.

1326. MULTIPLE TELEGRAPHY AND TELEPHONY WITH HIGH-FREQUENCY CURRENTS. (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 155—174, March, 1920.)

An article abstracted from *Telegraphen- und Fernsprech-Technik*, June, 1919, outlining the historical development of the transmission of telegraph and telephone signals by high frequency currents along wires, including Ruhmer's experiments in 1909. The arrangements due to Fassbender and Habann are dealt with in detail, and a summary is given of the tests of multiple telephony carried out by the Gesellschaft für drahtlose Telegraphie. The various filtering circuits used with the apparatus are described, and a number of curves and tables are also given of the high frequency resistance of various telephone line wires for different frequencies. It is stated that when using an earth return trouble was experienced by interference from high-power wireless stations working on the same wavelength, but that this was eliminated with complete metallic circuits.

1327. MULTIPLEX TELEPHONY WITH HIGH-FREQUENCY CURRENTS. Béla Gáti and K. W. Wagner. (*Elektrotechnische Zeitschrift*, 41, pp. 518—519, June 30th, 1920.)

Correspondence in which Gáti maintains that Wagner opposed him when he proposed this system ten years ago, whereas Wagner now writes in support of it. Wagner replies that Gáti's system was quite different from that now adopted.

1328. THE APPARATUS FOR HIGH-FREQUENCY WIRE TELEPHONY. (*Telefunken Zeitung*, 4, No. 21, pp. 63—66, July, 1920.)

A brief but well illustrated description.*

1329. HIGH-FREQUENCY WIRE TELEGRAPHY AND TELEPHONY. (*Telefunken Zeitung*, 4, No. 21, pp. 67—69, July, 1920. *Elektrotechnische Zeitschrift*, 41, p. 455, June 24th, 1920—Abstract.)

Account of lecture given by Dr. Mayer in Berlin.

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* See RADIO REVIEW Abstract No. 1159, also pp. 715—716, November, 1920.

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1330. INTERNATIONAL TELEGRAPHIC AND RADIOTELEGRAPHIC CONFERENCE. (*L'Électricité*, 2, pp. v—vi, August 15th, 1920.)

A brief report of an international conference held in Paris from July 7th—13th, 1920, all the European States being represented. As a result of the deliberations it was decided that each country should remain entirely free in the choice of its radio communications and of the method of effecting them, provided that the transmission did not interfere with the working of other stations. Special press and other services could also be arranged. It was recommended that all commercial services should as soon as possible be effected exclusively with undamped waves and that when the traffic exceeded 20,000 words per day high-speed automatic apparatus should be employed with facilities for simultaneous transmission and reception.

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2. Books.

ÉTUDE DE QUELQUES PROBLÈMES DE RADIOTÉLÉGRAPHIE. By H. de Bellescize. (Paris: *Gauthier-Villars et Cie.* 1920. Pp. 174. Price 16 frs.)

This is a collection of papers on various branches of the subject written and, in some cases, published during the last six years. They are arranged in chronological order without any regard to the nature of the subjects. The author's work is well known to all who are acquainted with the recent development of radiotelegraphy in France and is a guarantee of the value of this collection of papers. The first deals with the predetermination of the radiation of an antenna from the current distribution along it by the application of the ordinary Hertzian formulæ. The calculations for seven different aerials were checked by reception on a bolometer or thermal galvanometer at a distant station. Although the results were proportional to the calculated values no attempt seems to have been made to measure the actual radiated power. The statement that the bolometer abstracted the maximum possible amount of energy from the wave would not be true unless its resistance were suitably adjusted to the antenna. The author's statement that the loading coil is assumed to have no capacity is also untrue; it is assumed to have the same ratio of capacity and inductance per unit length as the aerial. The second paper contains a theoretical investigation of the efficiency of spark transmitters under various conditions. The third paper deals with methods of eliminating disturbances due to heavily damped waves.

The following paper is devoted to a theoretical study of the efficiency of various methods of coupling the receiver to the antenna and the effect of varying degrees of coupling and various resistance ratios, etc. Confirmatory experiments are also described. A paper dated December 1916 describes a resistance coupled amplifier for acoustic frequencies together with a study of the causes of the various troubles met with in such amplifiers. This is followed by a note on the adjustment of wavelength and coupling in an impulse transmitter; in our opinion this note suffers from an absence of explanation. In the following paper the author investigates the errors introduced into the reception of wireless signals by the various stray capacities such as those introduced by anode batteries and the observer's body through the telephone receiver. The next paper deals with the design of small frame aerials. In a paper on the application of Austin's formula to transmission problems a number of numerical values are given for the calculated electric field strength at various receiving stations due to distant high-powered stations and these figures are compared with the quality of the reception. The author concludes this paper with the remark that while authors discuss differences of 30 per cent. in transmission formulæ, those engaged in the transmission experience variations of 500 to 1,000 per cent. He also expresses the belief that improvement will not come by the invention of any method absolutely preventing interference, but by the accumulation of detail improvements. The following paper deals with the errors in the direction as determined by a rotating loop and with various methods of compensating the capacity to earth through the detecting apparatus. The two diagrams in Fig. 1 on p. 138 are obviously wrongly described. The concluding paper is probably the most important in the book; it is a study

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of the effect of the insulation of the towers on the radiation from the antenna. It is well known that in some cases in which great care has been taken to insulate the towers from earth, it has subsequently been found that the transmission is better with the towers earthed. It is important therefore to investigate the problem and be in a position to predetermine the effects of insulating or earthing the feet of the towers. When a tower is insulated its upper part may be regarded as forming an air condenser with the aerial, whilst its lower part forms a condenser with the earth. The effect of the current in the tower on the radiation and the effect of the losses in the insulation and earth at the foot of the tower on the efficiency of the station can be calculated approximately by making certain simplifying assumptions. The author applies his results to an actual station and gives experimental data illustrating and confirming the applicability of the method.

Although the various articles are so entirely disconnected and although in many cases they appear to be incomplete and call for further investigation, they will well repay careful study. They were obviously written for the most part to solve problems which arose during the war and which called for an immediate practical solution rather than an elaborate theoretical investigation.

G. W. O. H.

VOCABULAIRE EN CINQ LANGUES AVEC LES DÉFINITIONS OFFICIELLEMENT ADOPTÉES ET UN RÉPERTOIRE ALPHABÉTIQUE. By Henri Viard. (Paris: *Gauthier-Villars et Cie.* 1920. Pp. x + 108. Price 7 fr. 50.)

The text of this book consists of five parallel columns, corresponding to the English, French, Italian, Spanish and German versions of the various terms dealt with, broken up by numerous paragraphs in English and French, these being definitions pure and simple. Thus the work is in reality a vocabulary and a small dictionary and should prove very useful to those who try to read foreign radio literature with only a small amount of linguistic knowledge to their credit. One would not desire to administer too rigorous a treatment to the first edition of such a work. Nevertheless it is in the interest of all concerned that we call attention to a few omissions. The vocabulary does not include the following terms:—grid, plate, dynatron, pliodynatron, loop (or frame) aerial, filament, saturation, regeneration. An alternation is defined as half a cycle; this is not universally accepted.

E. BLAKE.

RADIOTÉLÉGRAPHIE PRATIQUE ET RADIOTÉLÉPHONIE. By P. Maurer. (Paris: *H. Dunod.* 1920. Pp. 386. Price 21 fr.)

This is a text-book of the class that gives a general description of the characteristics of electromagnetic oscillations and waves, and the circuits by which they may be produced and detected, without entering very deeply into the theory underlying the various phenomena.

The object of the author, as stated in the introduction, is to draw up a practical ensemble easy to understand, and containing as few formulæ as possible, holding the mean, between the advanced text-book which makes wireless telegraphy a collection of arid mathematical formulæ, and a purely practical volume containing simply that which is necessary to set up a receiving station.

The first chapter is an elementary study of the properties of electrical oscillations. Commencing with the alternating current, and circuits having inductance and capacity, it proceeds to give the conditions for an oscillatory discharge; the various sources of loss of energy are set out, and the consequent damping of the oscillations explained.

The propagation of electric waves along wires leads up to the action of an excited aerial. A number of mechanical analogies are used to illustrate certain of the phenomena. The next chapter, on the principles of wireless telegraphy, opens with a brief historical sketch and then gives a description of the properties of coupled circuits, the various types of coupling. The explanation of the relationships of the currents in two coupled circuits is rendered clearer by a number of diagrams showing the current amplitudes for various cases. Damping and resonance are also dealt with.

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The aerial and earth circuits, with an outline of the theory of propagation of waves round the earth is given, and the Austin-Cohen formula for transmission is set out.

The third chapter on transmission gives a description of the action of the supply circuit on the oscillating circuit, with the principle of low frequency resonance in the former.

The action of the induction coil and the various forms of interrupter used therewith are given, with the arrangements used for manipulation. The condensers, inductances and dischargers used are described.

In the chapter on reception, the various forms of detector,—coherer, magnetic, electrolytic, and crystal are given and the three-electrode valve with the method by which it functions, is fully dealt with. A number of relays for automatic reception are described including some not usually referred to in English text-books. Several circuits for using the three-electrode valve, including high frequency and low frequency amplifiers are given, but it would have greatly increased the utility of the description if details of the sizes of the condensers, inductances, etc., had been included. In some of the diagrams the circuits to which the incoming signals are applied are not clearly marked and Fig. 128 is printed upside down.

Chapter V. deals with continuous waves both in transmission and reception. The production of continuous oscillations by means of the arc, various types of high frequency alternator and three-electrode valve, is described. The Marconi smooth disc and the quenched spark methods are also dealt with in this chapter together with the various static frequency transformers. The principal methods for reception by the tikker, valve heterodyne circuits, etc., are also included.

The next chapter gives an account of the directional production and reception of waves, including the various types of aerials which have been used for directive transmission, with the Bellini-Tosi and moving frame methods for determining the direction of received signals.

In Chapter VII. is a description of the principal systems of wireless telegraphy. As may be expected the circuits employed by the French companies are given in more detail than others, the American systems receiving very scanty treatment. Amongst others may be noted the Marconi timed-spark method for producing continuous waves and several static frequency transformer circuits are described.

Chapter VIII. deals with radiotelephony and gives several of the principal systems which have been used such as the Colin-Jeance, Vanni, Ruhmer, Telefunken systems with a short description of the Alexanderson and Nixdorff magnetic amplifier and the various types of microphone.

Chapter IX. on "utilisation" gives details of the sets used by the French military and air forces, including details of several alternators designed for the latter. A number of ship sets are described and a short reference made to the direction finder.

Time signals and circuits for distant control by wireless are also dealt with and a list given of the principal stations with details of their times, etc., of working. The last chapter is on tracing faults in apparatus and methods for making measurements. The latter includes descriptions of wavemeters and bridges for measuring capacity, inductance and resistance.

The usual method for measuring strength of signals by the shunted telephone method is given, without any statement as to the need for using the total impedance of the telephone receiver in place of its direct current resistance. The formula is incorrectly given as audibility $= \frac{R_c + S}{3}$ where R_c = D.C. resistance of the telephones and S that of the shunt.

The methods for determining the characteristics and constants of three-electrode valves are also described.

The book includes a table of contents but no index, and there is a complete absence of all references. The information given appears to be well selected and well put together but the work naturally suffers from the impossibility of trying to treat the whole of wireless telegraphy in a single volume. In the description of the various systems, many have only the briefest reference.

Many of the diagrams are not clearly lettered, the lettering being in hand-written italics which are in several cases illegibly thin. In a few cases the scale on which the diagram has been reproduced is too small. The printing has not been well executed, in the copy sent for review several pages are imperfectly struck off.

W. H. NOTTAGE.

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Books Received.

THE CONSOLIDATED RADIO CALL BOOK. (New York: *The Consolidated Radio Call Book Company, Inc.* Second Edition. 1920. Pp. 160. Price $1.25.)

A COURSE OF MODERN ANALYSIS: An Introduction to the General Theory of Infinite Processes and of Analytic Functions; with an Account of the principal Transcendental Functions. By E. T. Whittaker, Sc.D., F.R.S., and E. N. Watson, Sc.D., F.R.S. (Cambridge: *The University Press.* Third Edition. 1920. Pp. 608. Price 40*s.* net.)

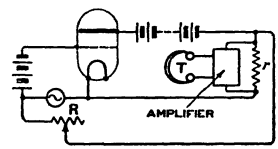
PRACTICAL AMATEUR WIRELESS STATIONS. By J. A. White. (New York: *Wireless Press Inc.* 1920. Pp. 133. 5*s.* net.)

Correspondence.

MUTUAL CONDUCTANCE MEASUREMENT.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—The circuit proposed by W. Schottky in *Telegraphen- und Fernsprech-Technik*, May, 1920,* for the measurement of the mutual conductance of a triode valve is the one suggested in England two years ago. (See J. A. Fleming's "The Thermionic Valve and its Developments in Radiotelegraphy," p. 142, and R. Stanley's "Wireless Telegraphy," Vol. 2, p. 348.) In using current of telephonic frequency with this circuit it is obviously undesirable to include the reactive telephone receiver coils directly in the anode and alternator circuits. This may be avoided by using a non-reactive resistance and a low frequency amplifier as shown in the accompanying figure.



For minimum sound in the telephone the mutual conductance $\partial i_a/\partial v_g$ is given by $1/(R + r)$, so long as the alternator impedance is large compared with the resistance r. If, however, the alternating voltage is introduced into the circuit by means of a few turns of wire of small impedance, linked electromagnetically to the alternator circuit, the value of $\partial i_a/\partial v_g$ is given still more simply as $1/R$.

E. V. APPLETON.

St. John's College, Cambridge.
October 20th, 1920.

* RADIO REVIEW Abstract No. 876, October, 1920.

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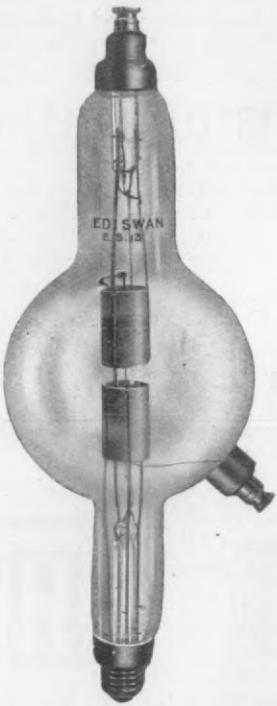

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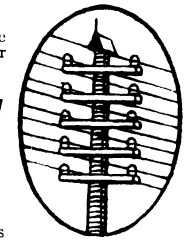

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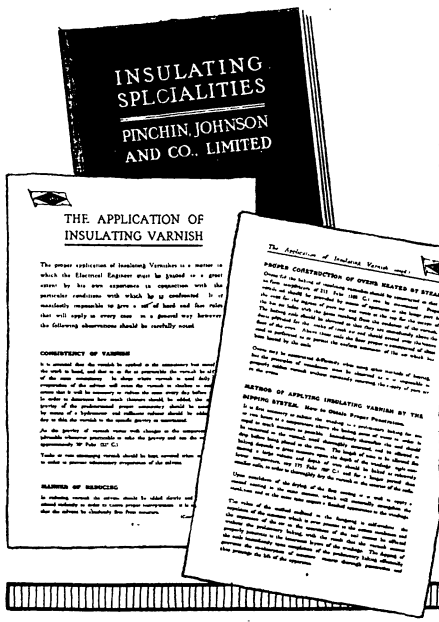

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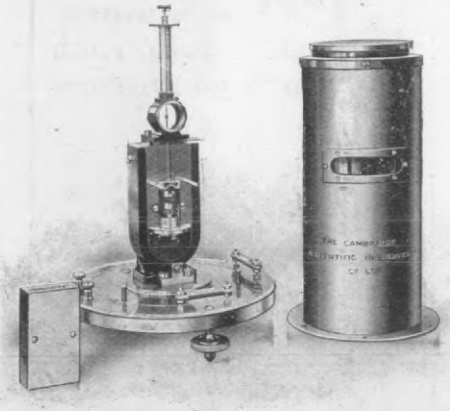

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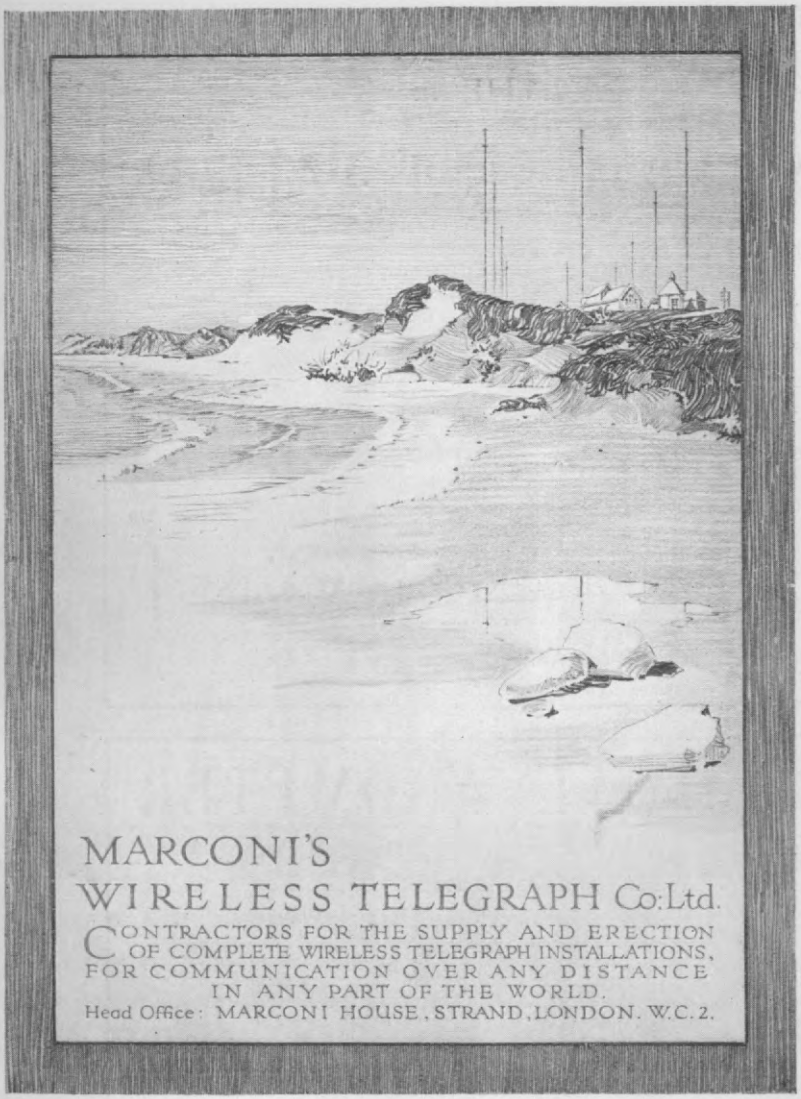
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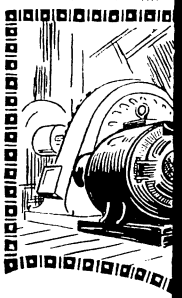

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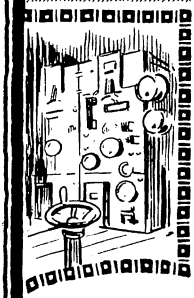

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